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HARMSWORTH POPULAR SCIENCE

EDITED BY ARTHUR MEE

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VOLUME THREE

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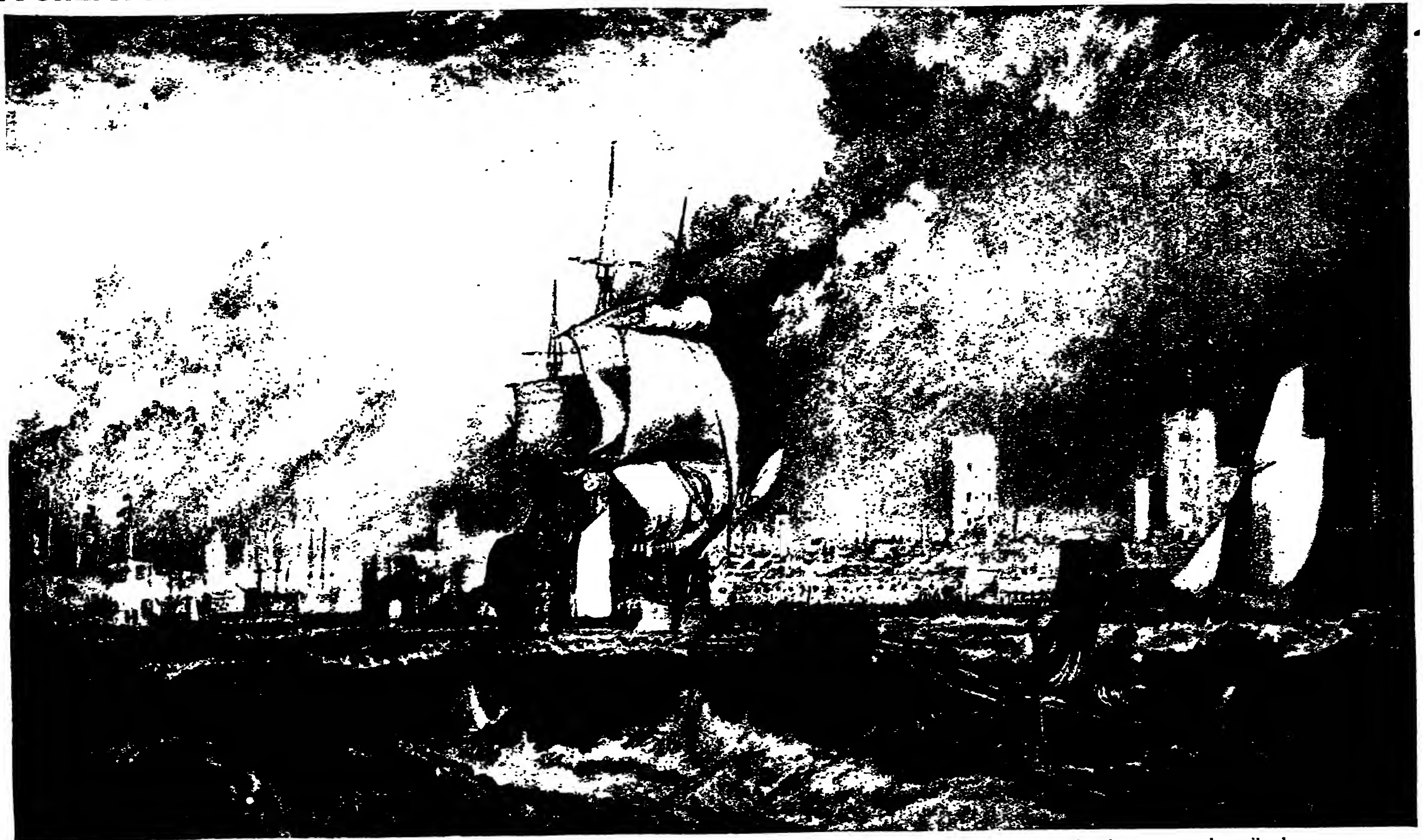
THE SPIRIT OF THE SUMMIT. BY LORD LEIGHTON, P.R.A.

CONTENTS OF VOLUME THREE

A GREAT PICTURE OF PORTSMOUTH HARBOUR BY THE MASTER OF ATMOSPHERIC PAINTING



Th[illegible] painting by J. M. W. Turner shows the way in which cloud and mist affect the clearness of a landscape, as described on page 1512.

IDEAS OF WORLD-MAKING

The Latest Theory of How the Different Heavenly Systems Took Their Present Positions and Motions

CELESTIAL COLLISIONS AND CAPTURES

We have not yet done with our theories of the solar system; the subject is too full of difficulties and possibilities. It is true that we have recognised the possibility of collisions, as in the formation of a gaseous nebula that might evolve somewhat after Laplace's theory, and also, as in the heating up of a collection of meteorites, so as to form a glowing nebula, sooner or later spiral. But there are other possibilities, more remarkable and fascinating even than these.

The possibilities of celestial collisions, and the consequent capture of colliding bodies by each other, are now widely discussed by astronomers. Here we shall deal in the main with the work of a distinguished pioneer, who has lived to find general attention drawn to views which he first expounded a generation ago. But just a word must be said in reference to the work of Professor See, of California, whose "Researches on the Evolution of the Stellar System" largely consort with the ideas of Professor Bickerton. Indeed, these two authorities, with many other astronomers of the present day, are agreed on a theory of the planets and their satellites which is startlingly unlike any that we have yet considered. It would be better if astronomy could give us one proven theory, but that time has not yet come. Meanwhile we must be patient, trying to prove all things, and the future will hold fast that which is good.

According to the students just named, the sun has captured his planets, and the planets have captured their satellites, or moons. These various bodies may all have taken origin in meteorites, and we may note how widely that view is now held. But the argument is that they were at one time independent, but have been brought into relation, if not subjection, by the influence of gravity, so we may speak of the smaller bodies, revolving round greater ones, as having been captured by them.

Professor See has adduced important arguments for the view that the peculiar "retrograde" motion of certain satellites of Jupiter and Saturn can best be explained by the theory of their capture by their primaries, though we have seen that another interpretation of the facts commends itself to another American astronomer. There is much interest in the observation that, if there be any resisting medium, through which the planets must travel, they will tend to fall nearer to the sun. It may be that there is some such resistance to the path of the planets. If there be, the smaller planets would feel its influence most, and Professor See argued, some four years ago, that this explains the huge collection of minor planets, or "asteroids," within the orbit of Jupiter. These asteroids were once, he argues, scattered far beyond their present limits, but have been contracted in their orbits in the manner he suggests. In thus approaching the sun, and taking up orbits within that of Jupiter, they have had to cross the orbit of that gigantic planet. Some few of them, chancing thus to cross the giant's path when he was at hand, have been captured by him, and are now described by us as moons of his. This is a very interesting speculation, and may prepare us for the idea of capture, about which we are to hear much more.

More than thirty years ago, in the Transactions of the New Zealand Institute, Professor A. W. Bickerton published certain views as to the importance of celestial collisions and captures. In another book, published about a dozen years ago, which he calls "The Romance of the Heavens," he reiterates these views; but astronomers

were not yet ready for such speculations, chiefly because the occurrence of a collision in the heavens was then thought to be excessively rare—an extraordinary accident, certainly no part of the orderly evolution of things. But the whirligig of time has brought its revenges, and within the last few weeks Professor Bickerton has delivered at the Royal Institution two lectures on "The New Astronomy" which must be of interest to all who speculate on these subjects, and not least to the Government and people of New Zealand, with whose aid he came over here to present his views to astronomers in this country. We shall here avail ourselves of those very recent pronouncements, in discussion of the theory which is itself now of such respectable age. The reader will not attach to the theory here given any more certainty than the nature of the evidence permits, or than its author would himself attribute to it. At the very worst, Bacon was right when he said that truth is more easily extricated from error than from confusion, and at the very best this is the truth of the major facts of cosmic evolution. The future will decide.

The Supposed Frequency of Collisions Between Bodies Whirling in Space

According to Professor Bickerton, then, and now a host of other astronomers besides, stellar collisions are not rare but common. We can photograph a hundred million stars in the Milky Way and its adjuncts. The number of dark ones cannot be less than seven times as many, according to this author, and his estimate is a modest one. Further, gravity is always at work, favouring collisions. Therefore, he argues, they must be not rare but common. Nor are they properly to be called accidental.

Before two suns collide they may have been falling towards each other, ever faster and faster, for hundreds of years. We should suppose that, when at last they met, they would do so completely, "full," as a billiard player would say. But it can be mathematically shown that such a collision could only occur if we imagine the two suns starting from a condition of rest. They would then be drawn together solely by gravitation, which would act, as we know, along the straight line connecting their centres of mass. They would thus be compelled to meet face to face. In such a case there would be formed a single body, a new sun, or nebula. One or both of its component suns might have been dark, but the tremendous force of the impact would be largely converted into heat, and a new bright sun would be the result, we may suppose. On the other hand, we have already seen that the first result of such a collision might be the formation of a gaseous nebula, of which an early stage was dark.

But such complete collisions, due to gravitation acting upon bodies initially at rest, must be unthinkably rare. It can be shown that if either of the attracted bodies has a motion of its own to begin with, the collision cannot be full, and it is in the discussion of these oblique or partial impacts that Professor Bickerton has reached such notable conclusions.

What Would Happen if Two Heavenly Bodies Did Collide?

For he argues that a partial or oblique collision between two suns, glowing or dark, would graze off a portion of both from the parts which came into contact, so that the matter which they had thus lost would form a third body.

It can be argued that the process of collision would always take from something like three-quarters of an hour to nearly an hour, whatever the mass of the colliding bodies, for the speed with which they met would be proportional to their mass. Thus in about an hour a new star would be born from the shed portions of the original pair, and this new star, the "third body," would have some remarkable properties and powers.

Here we can only consider the chief of these. It would contain an enormous endowment of energy, the force of the collision being spent, so to say, upon its devoted head, and thus it would expand, with truly explosive force, at a prodigious rate, which may be calculated at millions of miles an hour.

Have the Effects of Such Collisions Been Seen in the Heavens?

This explosion would be associated with a great and sudden effulgence of light, very likely thousands of times as brilliant as the sun, if we could see it from the same distance. But astronomers have seen such sudden blazings forth, in the dark depths of space, when, as it seemed, a new star, called for short a "nova," was born; and Professor Bickerton is able to argue, with much force, that the phenomena of the unparalleled new star in the constellation of Perseus, the star called Nova Persei, were capable of explanation by the theory which he had advanced many years before.

This star, at its brightest, was probably ten thousand times as brilliant as the sun.

But its distance was great—so great that the collision whence, according to our theory, this "third body" was produced probably occurred about the reign of James I., and the light only reached the earth, for astronomers to puzzle over, centuries later. This, however, is not the place for a further discussion of the "novæ," but we are to note that the observed facts of new stars seem to consort with the properties of the "third body" produced by a stellar collision, as those properties may be mathematically predicted.

What the Spectroscope Has to Say on the Matter

But here a new kind of observation comes into play. When we contrast the old and the new astronomy, as is often done, we are practically contrasting the knowledge gained by one instrument with that gained by another. The first instrument, always indispensable, and never more so than to-day, is the telescope. The second, the creator of the new astronomy, is the spectroscope. A lens made the old astronomy, a prism makes the new. The prism, or set of prisms, in the modern spectroscope enables us to analyse light; and thus, while the telescope could only answer *where*, the spectroscope can largely answer *what*.

Now, when we analyse spectroscopically the light from new stars, or "novæ," they answer, to some extent, the question *what*, which is instinctively asked of these stupendous phenomena by every student of the heavens. They flare up and die down, and so their light changes from day to day, or, rather, from hour to hour. We thus can obtain "light-curves" by putting together successive spectrograms of the light of these "novæ"; and if astronomers had the leisure and the money, doubtless they could arrange to apply the cinematograph principle—as, indeed, they surely must ere long—so that we could see the moving picture of the changes in the quality of the light given out by a "nova." The point for us now is that the character of the light-curve in such cases, so far as it has yet been recorded, appears to consort with Professor Bickerton's theory of the "third body."

Does a Third Incandescent World Form From the Clash of Two?

The evidence, however, is delicate, and requires much experience in the reading and interpretation of spectrograms, whose cipher is subtler than anything employed for the short-distance affairs we proudly call telegrams—that is, distance-grams—on the earth. We cannot here fill a dozen pages with rows of spectrograms which differ only in minute detail of line and colour, but the principle can be understood and remembered. It will be found to play an all-important part in all future astronomical inquiry.

But we must continue to trace the probable history of the "third body" thus born by a celestial collision, for we shall still have to describe, after that, its remarkable influence upon its parents. The incredibly stupendous explosion, which makes such a wonderful and surprising spectacle for the astronomer—who, of course, has no portent or warning of its coming—must profoundly alter the physical condition of the third body itself. Its substance passes far outwards in all directions, and in a comparatively short time its form is utterly changed, while its light has died away.

It probably produces great swarms of meteoritic matter, such as may thereafter form into spiral nebulæ. Its central part, denser and hotter, may remain as the glowing centre of a nebula of another type, called "planetary nebulæ" by astronomers, though the name has little to commend it. In short, we see here the possible beginnings of a new chapter in the evolution of the heavens, from which all manner of future orbs may be derived.

Have Double Stars Been Formed by Collision and Mutual Capture?

But we cannot do justice to the possibilities unless we remember the continued existence of the force called gravitation, which drew the two parent suns together and so produced the "third body." This new sun, containing what may be a very large proportion of the matter of the two that struck each other, must attract them, and be attracted by them. Thus the collision may have been such that, say, one-third of each of the two suns came in contact, and, for the sake of the illustration, we may suppose the suns equal in size and mass in this instance. Perhaps, then, each will have lost a third of its substance, and the upshot will be, obviously, three suns, each having two-thirds of the substance of the members of the original pair.

The new sun, formed by the combination of a third of each parent, is formidable from the point of view of gravitation. It captures the two reduced suns from which it was formed, so that, instead of passing on, and never having anything more to do with each other, they become united by a gravitational bond and form a double star, of which the members revolve unceasingly

round one another. The heavens, as we shall learn, are crowded with such double stars, and here is a theory which explains their origin. They have met and collided, forming a third body, which has captured them, or caused them to capture each other. It is an extraordinarily suggestive and brilliant hypothesis, and constitutes a genuine contribution to the science of astronomy, whether or not it corresponds to the actual facts of the sky.

But where, in such cases of double stars, is the third body ? we may ask. The answer may quite possibly be that the third body has become dissipated by the tremendous explosion to which it was condemned by its endowment of energy, and has formed, for instance, a dark swarm of meteorites, which may have gone their own course, in space and in developemnt, quite apart from its parents, though it has sufficed, at any rate, to link them to each other—to marry them, we may almost say.

What Might Happen if Great Stellar Bodies Passed Near Each Other

Of course, no single stereotyped answer can be given. The universe is not limited to a single formula. Colliding suns meet at various angles. They are of all possible variety in size, in density, in chemical composition. They vary as individuals in all these respects, and they further furnish new differences for each case by the contrast or likeness between them in these and other properties. Only the mathematician who was unaware of these differences would venture to lay down *the formula* for the results of a collision. What we can do, however, is to discuss the results of a collision in any one of a variety of supposed cases, some or all of which may actually occur. At any rate, the very common occurrence of double stars is an astronomical fact, and the probability of stellar collisions is extremely high.

It would, indeed, be strange if, somehow, the formation of pairs of stars did not depend upon their collision in greater or less degree. The qualifying clause is important. Very possibly, in many instances actual physical contact between the two suns, leading to the consequences above described, may not occur, even to the extent of a mere " grazing collision." But if two stars were to pass, or attempt to pass, each other, even at a distance of perhaps thousands of miles, the parts of each that were next each other might be attracted, so that a " third body," practically formed by the equivalent of a collision, would have to be reckoned with, no less than if the two stars had " bumped into " each other.

Nor must we overlook the importance and variety of the chemical issues that are involved in such collisions. Stars are made of atoms and molecules which differ as atoms and molecules on the earth, for the excellent reason that atoms and molecules everywhere belong to the same eighty-foı or so elements, and to compounds of theı made according to the same chemical laws.

The Sorting Out of Elements if a Collision or Approach Took Place

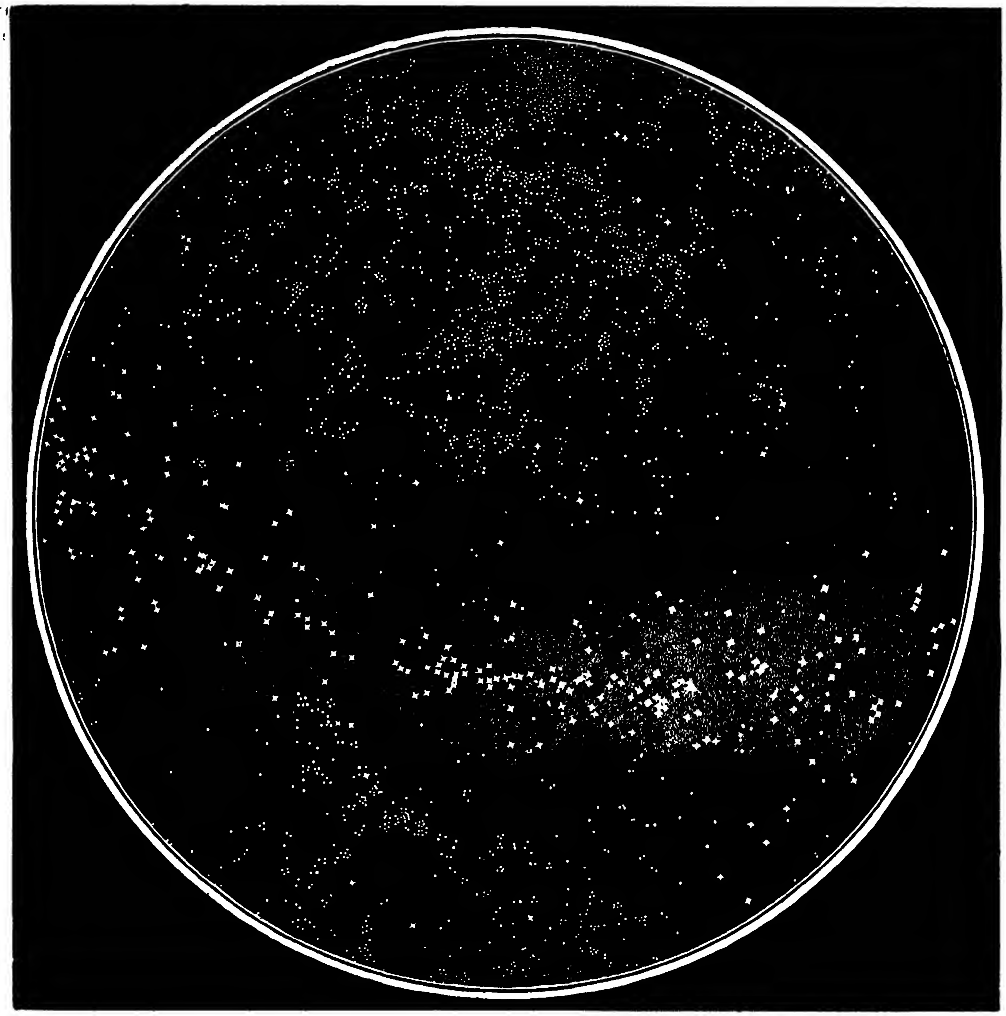
Atoms and molecules vary in weight or mass, and that fact alone must have great consequences in any such explosion as we have described. The lightest molecules and atoms will, of course, be thrown furthest. There will be what Professor Bickerton calls " selective dissipation " of the third body, a " selective molecular escape," whereby hydrogen and other light elements will be sorted out and sent farthest, to the limits of the nebula that is formed. Hence the outer parts of such a nebula, or such a meteoritic swarm, will largely consist of the lightest elements ; and here the reader will note the agreement with the notable argument of Professor Lowell from the varying chemistry and density of the planets of the solar system. The complexity, the uncertainty and difficulty, but the irresistible fascination no less, of such inquiries must surely be apparent to the reader; and if he asks for more dogma and rigidity of statement, he must remember that the new astronomy is still very young, and we are not yet certain what it will grow into. We must be content meanwhile to know that it is alive and growing fast. This is no time for putting upon it the strait-jacket of dogmatic conclusions.

The Many Kinds of Celestial Collisions that are Possibilities

Our more immediate concern here is with our own particular sun and his system. But the very fact that the sun is a star prevents us from attaining any but the most expensive success if we try to divorce solar and stellar astronomy. Least of all is this possible when we are studying the new astronomy, which puts on one side the *where* of astronomy, and calmly compares and contrasts bodies in the heavens that may be separated by unthinkable abysses, as if they were the units of a double star.

So here we must follow somewhat further the possibilities which are suggested by the theory of celestial collisions and captures. For the collision of two suns is not the

only possible case. A sun might rush into a nebula; two nebulæ might collide; star-clusters might collide with each other or with nebula or single stars, and so on. There is even the colossal possibility of a collision between two systems, or "universes," of stars; and that possibility is now asserted by the most recent observers to be nebulæ. A typical nebula of this kind is a double spiral, being composed of a more luminous centre (which would be the "third body," in Professor Bickerton's theory) with two long curved arms; and we commonly observe that these arms start from the centre at exactly opposite sides. Does it not look as if the theory which attributes



THE WHITE NEBULÆ AND STAR CLUSTERS IN THE NORTHERN HEMISPHERE

In this diagram, plotted on equal surface projection by Mr. Sidney Waters, the nebulæ, largely double spiral, are represented by dots and the star clusters by crosses. The belt is the Milky Way, which contains the bulk of ordinary stars. The nebulæ increase in number towards the Poles.

the very fact of the *double* system of suns in the midst of which we live.

The double character of many, if not all, spiral nebulæ is strikingly evident at a glance. Such nebulæ are very common, as are double stars. Naturally the idea suggests itself that if double stars have their origin in collisions, so also may the no less double structures which we call spiral such a great place in cosmic evolution to celestial collisions and captures might apply here, as to the double stars?

But the theory goes further. Our Milky Way itself, what is it? Let us totally ignore the question of size. Let us suppose that we could look at the Milky Way from some far-distant point outside it—for choice, a point at right angles to the plane of the

Milky Way itself, so that we could look down upon it and see it in its natural flatness, ignoring its stupendous size, and making our view-point so distant that we could afford to do so, and could see it all in small compass—what would it look like? Here, of course, is a question which must be dealt with at length later, but we must anticipate the answer in order to do justice to the work of Professor Bickerton. The Milky Way, thus looked down upon from a distance, would be realised as "a vast, irregular double spiral of a hundred million stars, and a still greater number of dead suns," to quote Professor Bickerton's recent words.

The Stupendous Conception of Passing or Colliding Star-Systems

If these be granted, so far as present appearances are concerned, have we any evidence to suggest that this apparently double structure is really of double origin, and that, in short, it has been formed by means of collision and mutual capture? The colliding agents, in such a case, must be not a couple of suns or stars, but a couple of systems of stars—a couple of "universes," to use the unfortunate contradiction in terms which several distinguished astronomers are now content to employ, in defiance of language and logic. These two stellar systems must be rushing together, seeking to flow through or past each other, and thus proceeding to form a vast double spiral nebula, of which the units are not molecules of gases, nor glowing meteorites, but stars. It is a stupendous conception, which would have amazed the most daring pioneers of astronomical thought in the past.

Is the Milky Way Itself a Double Spiral Nebula?

In fact, we *can* recognise two streams of stars in the Milky Way. They are flowing past each other in an orderly fashion. The average rate of movement of the members of one stream is markedly different from that of the members of the other stream. In various other details the two sets of systems of stars can be recognised as distinct. We cannot, without abuse of language, call them two universes, but we may agree with Professor Bickerton when he describes them as "two Cosmic Systems of different orders, formerly independent of one another."

No doubt this view of the Milky Way as a double spiral nebula may seem disproportionate to the reader, who has hitherto thought of spiral nebulæ as individual objects, constituting members of our stellar system. But size is nothing. An atom is a microcosm, a rotating system of units; there are atomic systems and solar systems; the universe can work, can evolve, can invent on an infinitesimal or an infinite scale. And perhaps we have underestimated the size of the spiral nebulæ, or rather of some of them.

Here comes a sensational observation. The most famous, the largest, and the longest known of all the spiral nebulæ is what we call the spiral nebula in Andromeda, of which a superb photograph is to be found on page 18. It is highly instructive to compare successive drawings and photographs of this body, culminating, for the present, in that referred to. We naturally ask, what is the real size of this object, with its regularity, its detail, and its complexity? The answer involves everything. Thus, if the nebula be really small comparatively, its light may be explained as given out by glowing meteorites. But if the nebula be very large, the separate bodies that give its light might be stars. We know there must be separate bodies, because of the spectroscopic characters of the light from the nebula.

Might not the Milky Way seen from Andromeda Look a Nebula Only?

The question can only be answered if we can ascertain the distance of the nebula; everything hangs upon the determination of that figure. The problem can be tackled, just as we tackle the problem of star distances, in the fashion to be discussed when we reach the stars. Here we need only consider results. They indicate a great distance for the nebula—so little is it affected, in our view, by the motion of our system. Many other bodies seem to pass us or be passed, and thus we can guess their distance, as we can guess that of the things we see from a moving train. But the nebula in Andromeda is so remote that our estimates are overwhelming. We use the unit called a light-year—the distance light would travel in a year. How many billions of miles a light-year is we may reckon by multiplying 186,000 miles or so by the number of seconds in a year. Only in stellar space can the mind of man need such a stupendous unit of distance.

Now, the nearest star is more than four light-years distant. The Milky Way has been estimated to be perhaps thirty thousand light-years in diameter—right across from one side of the Great Circle to the other. That figure, then, suggests some idea of the dimensions of our cosmic system. But astronomers of the highest authority, such as Sir David Gill, believe that the distance of the great nebula in Andromeda must

far transcend any such figure, so that it is nowhere near our stellar system at all. They name such a figure as *ten million light-years* for its distance. That is an unthinkable figure, but its meaning is not unthinkable.

If that, or anything like it, be the distance of the great nebula in Andromeda—which, nevertheless, from that distance makes such a magnificent figure in our telescopes—what must its size be? The answer is clear. It must be of a size quite comparable with that of the Milky Way itself; in a word, the nebula in Andromeda must be "a stellar system in a younger stage of evolution than our galaxy." Nor is there any longer any difficulty in believing that this galaxy of ours is a spiral nebula itself, and would be seen as such from an observatory on a planet of one of the countless suns in the stellar system, the cosmos in the cosmos, which we call the "spiral nebula in Andromeda."

But let us return from this necessary digression to consider the philosophic and astronomical meaning of the theory of celestial collisions and captures here set forth. The question really at issue is not merely the course and methods of cosmic evolution, to which this theory is an evident contribution. It is the question of the beginning and the *end* of evolution.

The Danger of Mathematicians Working on Too Few and Indefinite Data

The confident nineteenth century pronounced upon this subject, through the mouths of the mathematicians. Mathematics is a noble science, and mathematicians are wonderful and necessary people, but, of course, they can only reckon with the material given to them. Now, Lord Kelvin, an almost incomparable mathematician, but not a philosopher at all, argued that the universe is running down. It had a beginning, and must have an end. This is his celebrated doctrine of the "dissipation of energy."

Herbert Spencer never accepted this teaching. In remarkable words, which might well be quoted, and which are, in fact, being quoted, without quotation marks, by many thinkers to-day, Spencer declared that, while things were running down in one part of the universe, there might be upbuilding in another. He even pointed to astronomical illustrations of such upbuilding, as astronomers do now. He warned us all that other processes must be at work, which the mathematicians had not reckoned with, and showed how monstrously unphilosophical, how puerile from the standpoint of philosophy, is the idea of an ending or a beginning of things. In a letter reprinted in his "Life and Letters," Spencer notes how mathematicians argue from "few and quite definite data, where the data are many and indefinite," and adds "Lord Kelvin has furnished repeated illustrations of this." The warning is urgently necessary in other directions to-day, for events have justified it. For in the theory now before us, and in the admitted facts upon which it is rightly or wrongly based, we have a new set of data, numerous and widespread, which supply us with a factor of upbuilding as well as of destruction.

The Wonders of the New Theory of Constructive Destruction

Cosmic collisions were thought to be rare and destructive. The truth now appears to be that they are common and constructive. It is often, to quote with homage a remarkable metaphor used by Professor Bickerton in his final lecture at the Royal Institution in the present year, as if an explosion blew up some old collection of stones, the ruin of something that had been, and when the pieces fell they formed a modern palace. We see such "palaces" in all stages of their construction and maintenance and decadence and reconstruction whenever we glance at the sky.

It is really much better to be humble and much more scientific to have faith. There are more things in heaven and earth than are dreamt of in our philosophy. We often have to choose between one uncertain view and another; but if one of them involves the universe in limitations of time or space or power or fertility, we need trouble ourselves with it no further. Man must not permit himself to be "the measure of all things" in this sense.

Mistakes Made Through Thinking of Man as the Chief Object of Creation

He has always been trying to do so, and has always been proved wrong. That is the history of astronomy, from the dawn of astrology, which thought that the stars in their courses fought for lucky soldiers, to the modern theory of the nebula in Andromeda; from the view which pretended almost to remember the creation of the world, and expected the end of it at any moment, to the modern theory of its creative evolution, by a myriad modes, from eternity to eternity. No, indeed; if man is the measure of all things in a true sense, as he is, it is not because his dogmas can embrace the boundless universe, but because his thought, at its truest and best, is boundless and eternal too.

THE BLACK DUST-CLOUDS OVER A CITY

TWO VIEWS OF CHARLEROI, THE FAMOUS STEEL-MANUFACTURING CITY OF BELGIUM

These two drawings were made for "The World's Work" by Mr. Joseph Pennell

THE CONTENTS OF THE AIR

The Commingled Constituents of the Gas; Its Elasticity, Weight, Humidity, and Useful Dustiness

THE PLAYING-FIELD OF ELECTRICITY

We have considered the air in general in its larger relationships to the world; let us now consider, more in detail, its physical and chemical aspects.

Air, as we have said, is gas, and, being gas, it behaves like gas: it is elastic, as every air-gun demonstrates; it presses equally in all directions, as our own bodies witness; it expands with heat and contracts with cold, as every pneumatic tyre illustrates; and its volume at a constant temperature varies inversely with the pressure to which it is subjected.

Like all gases, air is very light: at sea-level a pint of dry air at a temperature of 60 deg. Fahrenheit weighs only ten grains, or about the weight of two ordinary pills. Light as air is in small quantities, yet in the huge quantities in which it occurs it exercises a considerable pressure. At sea-level the atmosphere exercises a pressure on each square inch of about the weight of 14¾lb., or approximately the weight of two gallons of milk.

Considering that there is a column of air about two hundred miles high pressing on each square inch, fifteen pounds seems light, but still, when we take larger areas and calculate the pressure, the result is rather surprising. Thus, at sea-level, on a square foot the pressure is about 2000lb., and on a square mile about 13,800 tons. The whole weight of the atmosphere is equal to a layer of mercury thirty inches high, or a layer of water thirty-four feet high, spread over the whole surface (oceanic and continental) of the globe, and, according to the calculations of Sir John Herschel amounts to 11⅔ trillion tons, or one-1,200,000th of the weight of the earth. A man of ordinary build living at sea-level is exposed to a pressure of about twelve to fourteen tons. Of course, such a pressure, if concentrated on a man's head or chest, would be crushing, but the pressure is exercised in all directions, up and down, from right side and from left side, from within and from without, and so it is hardly felt and does no damage. The film of a soap-bubble is exposed to pounds of pressure, yet it is not broken, since the pressure on the inside of the film equalises the pressure on the outside.

We have spoken of the air as having a certain weight and exercising a certain pressure *at sea-level*, but it must be clearly understood that the weight and the pressure at sea-level depend upon the enormous mass of superincumbent air. The air below is pressed upon by the air above, and thus becomes denser and heavier. If all the air were of the same density as the air at sea level, then a layer of air five miles high would suffice to account for the pressure we find at sea-level; but the air steadily diminishes in density as we ascend, and so the pressure at sea-level signifies a layer of air two hundred miles or so high. At sea-level, as we have mentioned, a pint of air weighs about as much as two ordinary pills, whereas at 18,000 feet it would only weigh about as much as one pill. At sea-level a man is exposed to an atmospheric pressure equivalent to fourteen tons, whereas on the top of Mount Everest the pressure would be only five tons. On the other hand, in the valley of the Dead Sea, which is below sea-level, a man would be exposed to extra pressure.

As is well known, the weight or pressure of the air is usually measured by a mercury barometer. The principle of the barometer is as follows:

If a tube about thirty-three inches in length, and closed at one end, be filled with mercury, and if the open end be closed by the thumb, and the tube so closed be inverted into a basin of mercury, *all* the mercury will not run out of the tube into the basin of mercury, even if the thumb be

BAROMETER AT BASE OF A MOUNTAIN

withdrawn, provided always the open end of the tube is kept below the surface of the mercury. But some of it will remain in the tube, forming a column of mercury rising thirty inches above the surface of the mercury in the basin. Now, that surely is a strange thing! The mercury is a heavy liquid, and the tube is turned upside down, and yet the mercury does not fall down, but, whatever the size of the tube, remains at a height of thirty inches. If a similar experiment be made with a tube of water, the water will be found to stand in the tube always about thirty-three feet.

What holds the liquids up? Undoubtedly it is the weight of the atmosphere resting on the surface of the basin. It forces the liquids up the tubes just as the pressure of the gas in a syphon forces the water up the central tube and out at the nozzle of the syphon. If this be so, then if we ascend a hill so as to reduce the weight of the superincumbent air, the mercury ought to fall in the tube; and fall in the tube it does. In fact, the mercury is found to rise and fall as the weight of the atmosphere increases and decreases, and, by noting the height of the mercury, we can measure the pressure of the atmosphere. That is the principle of the familiar mercury barometer, or weather-glass.

Other barometers known as aneroid barometers consist of a pile of thin elastic metal cases, air-tight and partially exhausted, which yield inwards as air-pressure increases, and expand again with any decrease of pressure. The movements of the metal case are transmitted to a lever, which, again, moves a pen or pencil, and this records the movement on a revolving cylinder for future reference.

At sea-level the height of the mercury column is thirty inches; at 18,000 feet (since, as we have said, the pressure at that height is only half the pressure at sea-level) the mercury column is only fifteen inches. At twenty-one miles high the barometer would stand at half an inch. During one of Coxwell and Glaisher's balloon ascents the mercury column fell to $9\frac{3}{4}$ inches, showing that the balloon had reached a height of six or seven miles.

In a general way, the barometer falls half an inch for each nine hundred feet of ascent, and thus altitudes can be roughly measured by barometric fall. But it must be remembered that when air is heated it expands, and thus becomes lighter, quite apart from the matter of altitude. It must also be noted that water-vapour in the air

diminishes the weight of the air. Further, the average normal barometric pressure at sea-level varies in different parts of the globe. There is a zone of maximum pressure on the sea between latitudes 30° to 35°, and the pressure then declines gradually towards the Poles.

We have spoken of the air as a collection of gases. What are the gases of which it consists, and where did they come from, and what do they do besides rushing about and exercising pressure ?

The chief gases in the atmosphere are oxygen, nitrogen, carbon dioxide, water-vapour, and argon, and there are traces besides of helium, krypton, neon, xenon, hydrogen, hydrogen dioxide, nitric acid, and ammonia. The average volume composition of the gases in the atmosphere is given in the following table.

Gases	*Volumes per cent.*
Oxygen	20·65
Nitrogen	77·11
Carbon dioxide	0·03
Argon	0·79
Water-vapour	Variable
Helium, krypton, neon, xenon, hydrogen, hydrogen dioxide, ammonia	Traces

The gases of the air are not chemically combined : they make up only a mechanical mixture wherein all the gases fly about freely and independently.

Let us look for a moment at the property of some of the gases.

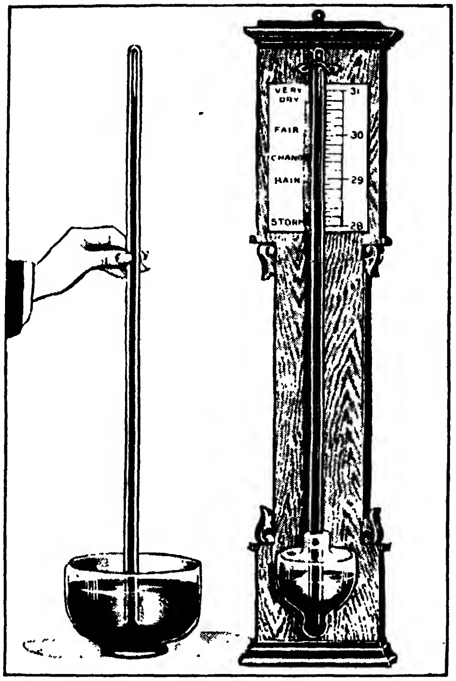
The wonderful gas oxygen, the king of all gases, was first discovered by Priestley in 1774. Priestley obtained it by heating red oxide of mercury and collecting the gas given off. He found that combustion took place better in it, and that mice lived better in it, and he came to the conclusion that it was very pure air—" between four and five times as good as common air." He inhaled it himself, and reported : " The feeling of it to my lungs was not sensibly different from that of common air, but I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but in time this pure air may become a fashionable article in luxury ? Hitherto, only two mice and myself have had the privilege of breathing it." A few years later the French chemist Lavoisier made an analysis of the air, and showed the place of oxygen as one of its constituents. In this way modern chemistry began.

Oxygen is a colourless, odourless gas.

BAROMETER TWO MILES UP A MOUNTAIN

Besides forming more than a fifth by weight of the atmosphere, it forms eight-ninths of all the water of the world, and more than half the crust of the earth. It plays the leading part in the vital function known as respiration, and on its chemical activity combustion depends. Sulphur, phosphorus, charcoal, and even iron wire burn vigorously in oxygen. The proportion of oxygen in the atmosphere is wonderfully constant, and extreme limits would seem to be 21 per cent. to 20·6 per cent.

Ordinarily a molecule of oxygen consists of two atoms, but sometimes it occurs in a three-atom combination. In this triatomic form it is known as "ozone," which has a very strong odour and increased chemical activity. It is usually formed by electrical discharges through the air, and by the oxidation of phosphorus. Owing to its great chemical activity it is a great purifier of the air, burning up all organic matter with which it comes in contact. Ozone is most abundant at the seashore, and least in the air of the crowded parts of towns.



THE PRESSURE OF THE ATMOSPHERE APPLIED TO THE MERCURY BAROMETER

If a glass tube about thirty-three inches long is filled with mercury, and the lower end of the tube is placed open in a bowl of mercury, the mercury in the tube will run into the bowl until thirty inches remain in the tube. Then it will stop. It is held up in the tube by the pressure of the air on the surface of the mercury in the bowl. If the air becomes lighter the mercury in the tube will sink; if it becomes heavier the mercury will be driven up higher. This is how the barometer works.

Carbon dioxide, discovered by Dr. Joseph Black in 1752, is also a colourless, odourless gas, and much heavier than air. In the processes of combustion and respiration, carbon and oxygen unite and form this gas, and it is also given off in large amounts from the ground, specially in volcanic regions. At ordinary temperatures and pressures water takes into solution about its own volume of the gas; and the carbonic acid solution so formed has a very corrosive action on the rocks of the crust of the earth.

It is from the carbon dioxide in the air that the green plants obtain their carbon; and since all animal life ultimately depends on vegetable food, carbon dioxide may be said to be the keystone in the arch of life; yet animals suffocate and lights refuse to burn if immersed in this gas. When carbon dioxide meets with lime it enters into combination with it, forming carbonate of calcium; and if lime-water be shaken up with air the clear liquid becomes whitish and opaque, owing to the formation of carbonate of calcium. Likewise, if the breath be bubbled through lime-water, the carbon dioxide in the breath will form carbonate of calcium, and will render the clear fluid turbid. The carbon dioxide can be liberated again from the lime by treating the carbonate of calcium with an acid, such as vinegar; and if eggshell, or a piece of chalk, or a piece of marble, or carbonate of calcium in any other form, be treated with a suitable acid the carbon dioxide effervesces out of the carbonate just as it effervesces out of aerated waters.

In open air the percentage of carbon dioxide hardly varies, but in closed rooms it often increases considerably, and the increase is usually considered a criterion of the impurity of air.

Nitrogen is a most negative gas: it has no colour, no smell, and no pronounced affinities. It simply dilutes the other gases of the air, and gives the atmosphere more weight, force, and filtering capacity. It is, moreover, the original source of the nitrates in the soil, from which plants assimilate their nitrogen.

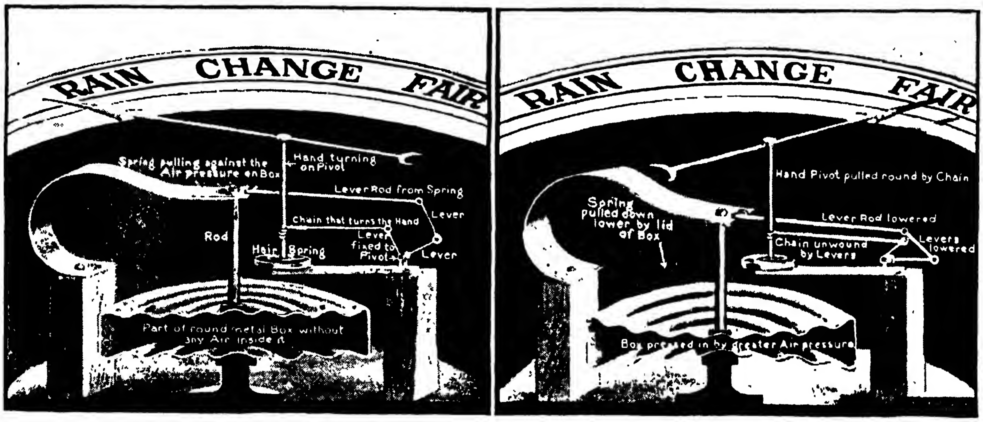
The gases of the atmosphere are always well mixed; and if any gas be formed in excess in any open locality it is quickly dispersed and lost in the general mass of the atmosphere. This is due to that movement of gases known as *diffusion*, which causes them to intermingle automatically with each other until a perfect admixture is effected. If liquids of different densities are mixed together they tend to separate into layers one above the other, according to weight; but, owing to this

property of diffusion, the gases of the air, though they differ in weight, not only do not tend to separate, but even if placed in separate layers soon intermingle.

Like all gases, the gases of the air can be converted by cold and pressure into liquid and solid. At a temperature of 350° Fahrenheit below zero, air becomes a liquid, and at a still lower temperature it becomes solid.

Water is a liquid in a condition of very unstable equilibrium. At high temperatures it rapidly evaporates, and even at freezing-point a certain amount of evaporation goes on. Water-vapour is simply water in the form of a gas, even as ice is water in the form of a solid; and mixed with the oxygen, nitrogen, carbon dioxide, and other gases there is always a certain amount of this water-gas in the air. Water-vapour is lighter than oxygen and nitrogen. Thus at a temperature of 50° Fahrenheit it is 133 times lighter than air.

It is commonly imagined that the air sucks up the water, but that is an erroneous conception of evaporation. The air merely helps to warm the water, and helps to keep it warm, but even if there were no other gases in the air the gas of water would rise. It is heat that agitates the molecules of liquid water, and that drives them into the air as molecules of gas that dash to and fro. The higher the temperature of the air, the more water-vapour will the atmosphere contain. Thus, at 32° Fahrenheit the air holds 1-160th of its weight of water-vapour; at 59° Fahrenheit it holds 1-80th of its weight, and at 86° Fahrenheit it holds 1-40th of its weight. Roughly, every 27° Fahrenheit doubles the amount of water-vapour the air can hold in proportion to its weight. *Vice versa*, every fall of 27° Fahrenheit halves the air's capacity for water-vapour, and, accordingly, any drop in temperature is liable to cause a deposition of water-vapour from the air in the form of mist, cloud, rain, or dew. If the air at any temperature contain its full quantum of water-vapour—if it be saturated, that is to say —then a very light fall of temperature will suffice to reduce some of the vapour to a liquid state; but if the air be not saturated a considerable fall may take place without condensation of the vapour.



PICTURE DIAGRAM OF THE ANEROID BAROMETER AND PRINCIPLE ON WHICH IT WORKS

The amount of water-vapour in the air may be expressed either by its weight per unit volume (absolute humidity), or by the proportion it bears to saturation (relative humidity). Thus we may say that air contains 9·4 grammes of water-vapour per cubic mètre; or we may say that it has a "relative humidity" of 75 per cent.—*i.e.*, it contains 75 per cent. of the total water-vapour it is capable of holiding.

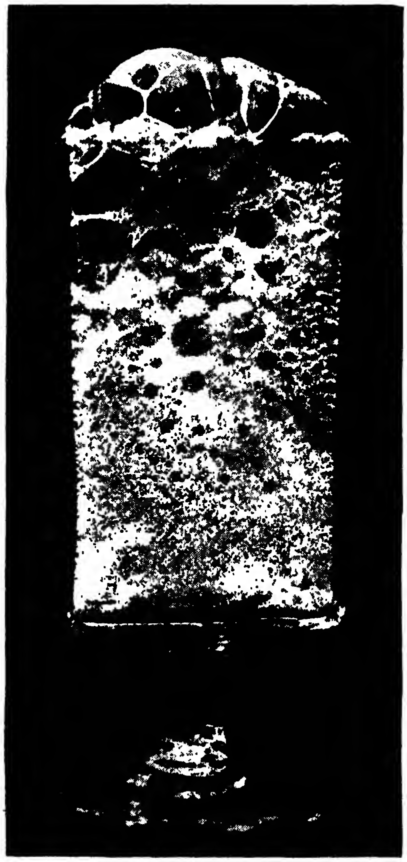
Meteorologists usually find the absolute and relative humidity of the air by a comparison of the readings of a wet and dry bulb thermometer. If we wrap a wet cloth round our head it cools our head; and likewise if we wrap wet muslin round a thermometer bulb (thus making it a wet-bulb thermometer) it cools the thermometer, but the cooling in both cases depends on the rapidity of evaporation, and this, again, depends on the relative and absolute humidity of the air; and if we know the difference between the wet and dry bulb reading it is easy, with the aid of formulas, to find the absolute and relative humidity of the air.

The average relative humidity of the air in this country is about 75 per cent. As the air cools at night it becomes able to hold less

and less water-vapour, and finally layers near the ground may become supersaturated, and deposit some of their vapour as dew. As the morning sun warms the air again, the relative humidity falls. In California the relative humidity may drop from 100 per cent. at dawn to 22 per cent. at noon. A hot wind may quickly lower the relative humidity 50 or 60 per cent. There may be as much as 80 per cent. difference between the relative humidity of cool inside and warm outside air under a tropical sun.

In dry, hot countries the relative humidity is very low. At Assouan the mean relative humidity in the hours from 10 a.m. to 6 p.m. is 30·5. At Bloemfontein the annual mean relative humidity is 58·5. In the heart of the Libyan desert it may be as low as 9.

It has been customary to attach a good deal of importance to the relative humidity of the air; and meteorologists note the relative humidity as if the percentage figure had a precise and definite significance, but, as a matter of fact, relative humidity has very little meaning considered by itself. A relative humidity of 60 per cent. at freezing-point has a very different meaning from a relative humidity of 60 per cent. at higher temperatures, for cold air with a relative humidity of 60 per cent. can hold very little additional vapour, while hot air of the same relative humidity has much greater capacity for retaining its vapour.



THE EFFERVESCENT LIBERATION OF CARBON DIOXIDE

The absolute humidity of air—*i.e.*, the actual amount of water-vapour in it—is of especial importance, in that water-vapour both contains a large amount of latent heat, and also reflects back the radiant heat of the earth.

The higher we ascend, the rarer and colder does the air become, and therefore the less water-vapour does it contain. Half the total water-vapour of the atmosphere is below 6500 feet, and three-quarters below 13,000 feet, while at 29,000 feet, the height of Mount Everest, there is hardly any water-vapour in the air at all. Not only is high air dry air, but, owing to its rarity, it is very *drying* air; and at high altitudes we find that dead animals dry up and mummify without decaying.

When water-vapour condenses in the atmosphere, it may form either rain or clouds or mist. When it condenses on cold objects near the ground, it is called dew.

The other gases of the atmosphere—argon, helium, neon, krypton, and xenon—are so inert, and occur in such small quantities, that they need only be mentioned.

Besides gases, however, the air contains dust, germs, and radio-active matter.

All small particles suspended in the atmosphere, whether grains of salt, or grains of sand, or organic débris, must be considered dust; and dust particles of some kind or other are found everywhere in the lower atmosphere. The winds steal dust from the crust of the earth, from fields and deserts. The ocean breezes snatch salt from the ocean spray.

The volcanoes shoot dust high into the heavens. The furnace chimneys soil the sky with their carbon soot. Everywhere there is dust, dust, dust. It is surprising, too, to find how far dust can be conveyed. The writer has seen the sun darkened in Teneriffe by clouds of dust borne across the sea from the desert of the African mainland. Red dust from China has been found in California, and fragments of microscopic animals have been found in the air of Portugal which must have been carried right across the Atlantic from America. The smoke of burning Chicago reached as far as the Pacific Coast, and African micro-organisms have been detected in the air of Berlin. The eruption of Mont Pelée strewed dust on Barbados, 100 miles off, to a depth of several tons to the acre.

Dust is also added to the atmosphere by ıeteorites. Every twenty-four hours no ıss than 20,000,000 meteorites visible as hooting-stars invade our atmosphere; and ıeteoric dust can be found both in the air ınd in the silt at the bottom of the sea, hough its fall there may not be recent.

Insignificant as dust may seem, it is yet ıf great importance to the world. In ırdinary quantities, as we have seen, it is he main cause of the blue colour of the sky; vhile the coarser, thicker dusts produce ariegated and gorgeous colour effects. The ;orgeous sunsets produced by volcano dust are well known, and the course of the dust round the world can be traced by the clouds of glory that accompany it. Marvellous sunsets for a long time bore witness to the dust ejected by the volcanic eruption on the island of Krakatoa, in the Sunda Strait, and the dust was carried round the whole earth. Edward Whymper, the famous explorer and mountaineer, thus describes the colour effects produced by the volcanic dust of Cotopaxi: "We saw a green sun, and smears of colour something like verdigris-green high up in the sky, which changed to equally extreme blood-reds, or to coarse brick-reds, and then passed in an instant to the colour of tarnished copper or shining brass. No words can convey the faintest idea of the impressive appearance of these strange colours in the sky—seen one moment and gone the next—resembling nothing to which they can properly be compared, and surpassing in vivid intensity the wildest effects of the most gorgeous sunsets." And the function of dust is more than artistic. Ordinary everyday dust it is that gives sunlight by day its soft and diffuse character, by catching and reflecting the sun's rays. Except for the dust, as we have said, we would see the sun and the stars in a black sky; the surface of the earth would shine, but it would shine as a glow-worm in the dark. Light passing through a dustless dark box is unseen, and only if dust be added to the air does the air become sunlit.

THE CONDENSATION OF WATER-VAPOUR IN THE AIR; MIST IN THE WOODS

A very interesting illustration of this principle is seen in the lighting of the streets of Chicago. A beam of electric light is shot like a cannon-ball along the centres of the long, straight streets. "The streets are thus satisfactorily lighted by the minute particles of dust reflecting some of the light

from the beam in all directions on to the pavements and sides of the houses. If the air in the streets were free from dust, the streets would, by this system of lighting, be in absolute darkness."

The soft, shimmering light of twilight is produced by dust in the upper layers of air reflecting the light of the sun after sunset—that is, after the sun has set below our horizon. Dust colours the sky and lights the sky, then; but, paradoxical as it may seem, dust also darkens the sky, for dust is the scaffolding of clouds and mists and fogs. Dust, the lightener, darkens; dust, the dry, makes the rain-clouds. Water-vapour is itself invisible; it is only when it condenses as minute drops of water that it forms clouds, and mists, and fogs; but, without something to condense upon, the water-vapour cannot condense, and the dust provides cold condensing surfaces. If there were no dust in the air we should have no mist, no clouds, no fog. That might seem a small deprivation, but it would have unpleasant consequences. The air would become supersaturated; and, if there were no particles in the air for the vapour to condense upon it, all objects on the earth's surface would become condensers. "Every blade of grass and every branch of tree would drip with moisture deposited by the passing air; our dresses would become wet and dripping, and umbrellas useless. But our miseries would not end here. The insides of our houses would become wet; the walls and every object in the room would run with moisture."

Whether the water-vapour condenses as cloud, or mist, or fog, depends on the quantity of dust present—the scantier the dust, the coarser will be the condensation.

The amount of dust in the atmosphere varies with the altitude, direction of the wind, locality, and many other circumstances. As a rule, the air is most laden with dust in large cities, and indoor air is dustier than outdoor air. The amount is usually stated as so many particles per cubic centimètre. On the top of the Rigi mountain, in Switzerland, 420 to 12,000 particles per cubic centimètre were found; and over the Pacific Ocean 280 to 2125 per cubic centimètre. In London outside air the number of particles found run as high as 80,000 to 116,000 per cubic centimètre; while in a laboratory 1,860,000 particles per cubic centimètre, or 30,318,000 in a cubic inch, were counted. Smoking-rooms contain even more, since every puff from a

HOW SALT FROM THE SEA-SPRAY IS CAUGHT UP BY THE WIND

TWILIGHT'S SOFT, SHIMMERING LIGHT, THAT IS PRODUCED BY DUST IN THE UPPER AIR

cigarette contains, it is calculated, about 4,000,000 particles of dust.

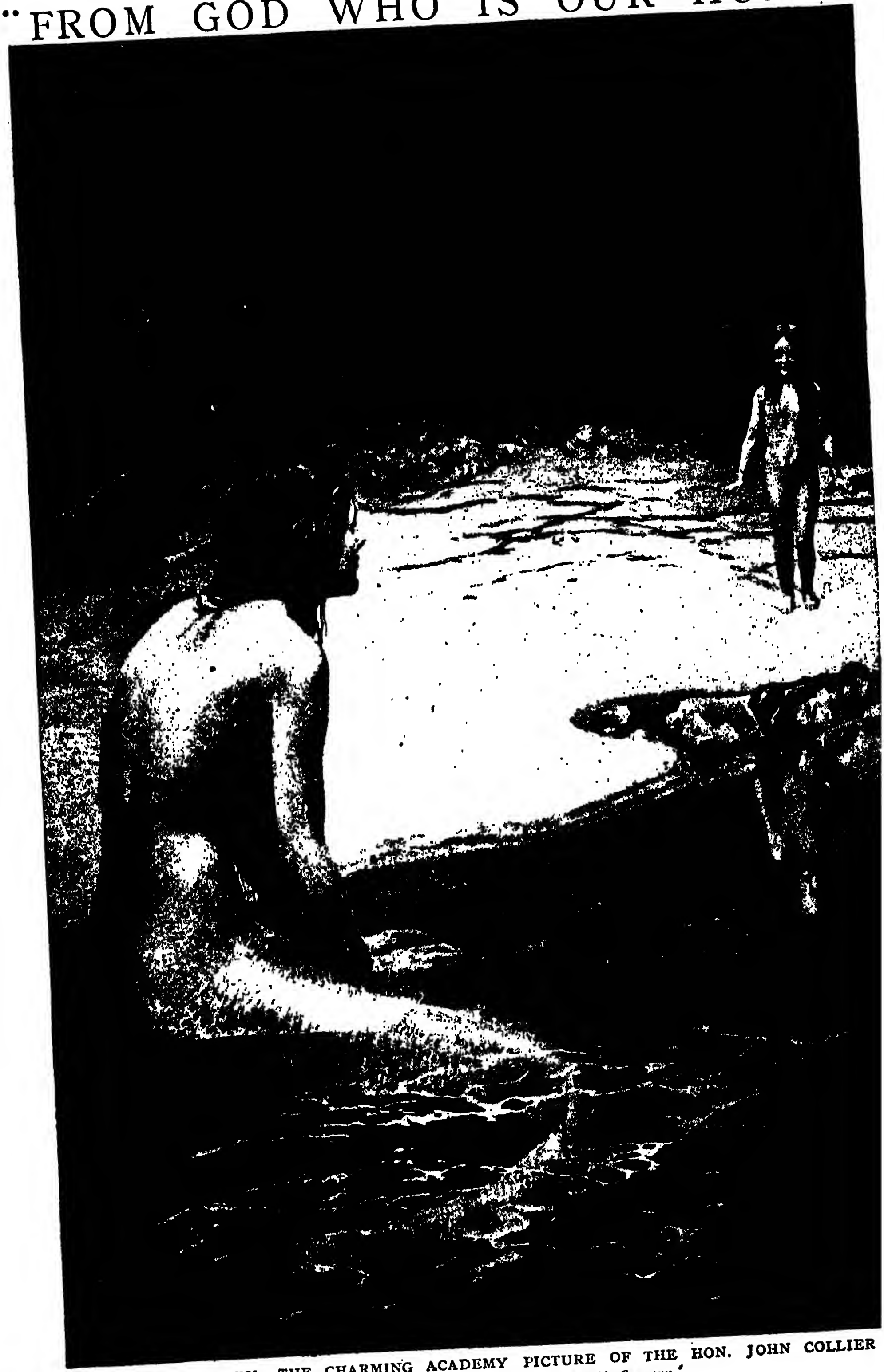
Germs must be considered along with dust, for they are just a special kind of dust. The ubiquity of germs is most surprising. Every sweet liquid left uncovered is soon invaded by yeast-cells and other fermenting organisms, and all dead organic matter is soon attacked by the microbes of putrefaction. But still germs are not everywhere, and they are by no means so ubiquitous as lifeless, inorganic dust.

Tyndall exposed a thousand tubes to the air of London, and found that every one was invaded by germs. On the other hand, no germs invaded twenty-seven tubes open to air on the Aletsch Glacier (8000 feet). Indoors, in dark, dirty rooms, germs abound, and in a gramme of dust from a room in Paris no less than 2,100,000 germs of various kinds were found.

It is a well-known fact that the atmosphere is charged with electricity, as shown by the electrical phenomena accompanying a thunderstorm. But the ai is always charged with electricity, even in calm weather, and there is always a certain amount of electrical tension between earth and atmosphere. The tension is highest in winter, and lowest in summer, and is especially increased by the condensation of vapour. Generally the upper strata of the air are charged with negative electricity, just as the surface of the earth, while the intervening layer of air is charged with positive electricity. The electrical tension is so great in clouds that lightning will sometimes leap across between clouds as far as ten miles apart.

On mountain peaks the electric tension produces sensational phenomena. An observer on Pike's Peak gives the following account of his experiences. "His hair stood erect, crackled, and the pricking sensation to the scalp was extremely painful. The peculiar electrical odour was strongly recognised. To protect his head he put on his black felt hat and returned to the roof. But a few seconds elapsed before he was fairly lifted off his feet by the electrical fluid piercing through the top of his hat, giving him such a sudden and fiery thrust that he nearly fell from the roof in his excitement. Instantly snatching the hat from his head, he observed a beam of light, as thick as a lead pencil, which seemed to pass through the hat, projecting to about an inch on either side, which remained visible for several seconds. The top of his hat was at least two inches from his head when the fiery lance pierced him. When the fluid began to thrust its fiery tongue into other parts of his body, he was spurred to a hasty but brilliant retreat."

"FROM GOD WHO IS OUR HOME"



THE LAND BABY—THE CHARMING ACADEMY PICTURE OF THE HON. JOHN COLLIER

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WHERE DARWINISM HALTS

It Does Not See Life Finding by Inward Impulsion a Highway Up to the Mind of Man

PSYCHICAL FORCE IN PHYSICAL FORMS

Darwin sleeps in Westminster Abbey, as he should. All men who honour noble qualities of mind and temper honour him. His services to biology are immense and indispensable. Yet, while we "praise famous men," we must pass on, for we are alive and life ever presses forward. That, indeed, is the leading idea of the great thinker Henri Bergson, to whom we have already referred on many occasions, and who has carried the theory of evolution to a further point than any of his predecessors. Before we pass to the scientific detail of the great problems of heredity and variation, we must complete our history of the idea of evolution by giving due discussion to what this thinker has taught us. Yet again we shall feel that the nineteenth century has gone for ever, and this is the twentieth.

We have accepted the mechanical laws of natural selection, which is ever at work destroying the least adapted to the conditions of life. We must further accept the truth that life, in all its evolution, never transcends physical laws. No living being creates or destroys an iota of energy or an atom of matter. The processes that occur within it obey all the laws of physics and chemistry. The living being is demonstrably an internal combustion engine turning the chemical energy of carbon, hydrogen, and oxygen into motion, just like the engines which man makes. We talk of "organic chemistry," "physiological chemistry," "bio-chemistry," but we know that these are all part of chemistry as a whole, and break none of its laws. Life and the evolution of life, whatever their ultimate explanation be, work through and exist in the material world, and obey its rules. It is a great achievement of science to have established these truths once and for all. Nothing taught us by Bergson, or by any subsequent thinker, will shake them.

But we have been apt to make the stupendous mistake of supposing that, because the living being obeys physical laws in its working, it is simply their product, and nothing more. Yet man makes a motor-car, and obeys physical laws in the process, and we do not say anything so absurd as that the maker *is* the motor-car, or that he is not directing physical laws for his own purpose. Just so Life made the body of the man, itself an internal combustion engine and motor-car, obeying physical laws, but not therefore their product. The truth is that the mechanical-materialist, physico-chemical theory of life has confounded the mechanism of life with the nature and essence of life. Of course life uses mechanism, as the poet or the musician does; life even *makes* the mechanism it *uses*, and obeys the laws of physics and chemistry in its uses, just as the musician obeys them in his instruments. But life and the musician still remain to be reckoned with.

There is no gainsaying the fact that the theories of evolution which we have already studied are essentially mechanical, and they depend upon a mechanical theory of life. Natural selection, for instance, is essentially a mechanical process, which therefore applies just as well to atoms as to living things. We have already learnt that the theory of natural selection assumes the production of *chance* variations, in all directions, some favourable to survival, others unfavourable, and the favourable are chosen. But it is a cardinal part of this mechanical theory of evolution that the variations are at random, essentially accidental, and that they exhibit, and flow from, no purpose, or intention, or design, behind things and working through them. The evolution of man, and his mind, and his feelings, and ideals is essentially, on the theory of natural selection, the consequence

of the automatic survival of chance variations in living organisms, from the amœba upwards—in short, the making of man is a chapter of accidents.

Thus, if evolution, as understood in the nineteenth century, did anything at all, it banished *design* from the living world. We might incline to say that the eye was made, or evolved, *in order to* see, limbs in order to move, and so on; but that was only apparent. We were taught that the eye, the limb, the brain, were products of random variation, which owed their survival and perpetuation to their "survival value." At all costs, we were required to exclude from our description of the living world, and all its parts, any terms or ideas which involved the suggestion of purpose, design, "final causes," or teleology, to quote the classical phrases for this idea. The doctrine of Darwin was set up as established by science and as demonstrably discrediting the view, held from all time, which was expressed in 1802 in Archdeacon Paley's famous work, "Natural Theology; or, Evidence of the Existence and Attributes of the Deity." This book gave fine expression to the idea, familiar to all of us, that the facts of Nature show mind and design behind them—whence the argument may be made for an Almighty Mind, and thus we have a "natural theology."

The Return of the Ideas of Design and Purpose to Physical Science

Paley said that, if walking on a heath, we found a watch and examined it, we could not resist the inference that there must have been a watchmaker, so clear is the evidence of design in the watch. But living things, he argued, as millions have argued before and since, show evidence of design, as the watch does, and require us to draw the same inference.

The opposition between this view and Darwin's is absolute. Paley points to the eye, which seems to be crammed with evidence of design. Darwinism argues that its features are the product of random variation, fixed by natural selection. According, therefore, to what we may call the standard scientific teaching of to-day, which has been spread broadcast by the enemies of religion in especial, we are totally to exclude from our interpretation of the living world anything of design or purpose—an exclusion which, evidently, has serious consequences for the theology that found evidence of a Designer in Nature, according to Paley's argument, so long accepted as adequate by the whole modern religious world.

But, in point of fact, we cannot describe the world of life, and the features of its inhabitants, without using terms that involve the idea of purpose. We cannot describe the lens of the eye, and the muscle which alters its shape, for near or for distant vision, without saying what we have just said, that they exist *for* near or for distant vision. To describe the anatomy and physiology of any living thing without using such language is simply not to describe them. The most convinced champions of the idea that there is no design or purpose in living things have to use language which implies it directly they begin to describe them. That point will weigh with us when we come to frame a new theory of evolution, and here is another.

The Inadequacy of any Theory that Cannot Account for Mind

We find mind associated with life, and here is a complication for our materialist-mechanical theory. We study the chemical mechanism of the living body, and find that it involves the use of ferments. All manner of things happen, in the digestive canal of man or any creature that has a digestive canal, or indeed in the cell we call an amœba that has no digestive canal, which depend upon fermentation; and when we discover that *all* the essential processes of a living organism depend upon fermentation, even that the development of the adult depends upon the presence of ferments, or substances preliminary to ferments, in the germ cells, we incline to frame the bold and engaging generalisation that "Life is a series of fermentations." But mind is to be explained also. No theory of life which does not explain its psychical side is adequate. This psychical side is not a late accident. Mr. Francis Darwin has found evidence of sensation in plants. Minute microscopic organisms, animal or vegetable, when closely examined, are found to exhibit choice, to try and to learn. They *behave*. Indeed, the evolutionist is bound to expect to find traces of mind in low forms of life, and such traces, and more than traces, exist.

When Perfect Mechanical Adjustment has been Reached Life goes on to Further Adjustments

Now it was all very well to look at the physical aspect of a living thing, an amœba or a man, to follow digestion, respiration, development even, and perhaps reproduction also, and say that "Life is a series of fermentations." But the proposition, "Mind is a series of fermentations," is simply silly; and involves the conclusion

that our assertion about life was only an assertion about its mechanism.

It follows that we require a theory of evolution which shall take into account the psychical aspect of life, and not the physical aspect merely. We have far more to account for than our current theories recognise. Take, for instance, adaptation. Paley, speaking for a great host, sees in adaptation, as a thousand species illustrate it, palpable proof of design. Darwinism and mechanical evolution see in it the action of natural selection, which permits the survival of the best-adapted. But even supposing that this theory told us anything of the origin of the best-adapted, as we know it does not, there are facts which it does not account for. Life is not merely adaptation—even if "merely" be the right word. We have recognised and have insisted upon adaptation so much that we have ignored a most tremendous fact. Herbert Spencer's valuable and suggestive definition of life was that it is "the continuous adjustment of internal to external relations." That, of course, is no real definition—since we are entitled to ask adjustment *of what?*—but it is a description of a great fact of life. Its result is adaptation. Now let us suppose that the "external relations" remain fixed, and the living thing adjusts its "internal relations" to them. Life, on this definition, should stay there. The adapted species should persist and persist.

Is There not an Aim Purposive and Psychical Behind all Evolution?

But the stupendous fact which this description of life ignores is that life does *not* stop when it has achieved adaptation, the perfect adjustment of internal to external relations. The amœba is adapted, and the alga and the sponge and the oyster. Life produces these adaptations, but it is not satisfied. Our theory does not begin to account for the continued production of new forms of life, higher, more complicated, more delicate, by no means necessarily better adapted. Once adaptation is achieved this continued process of innovation is unaccountable on any existing theory of evolution or definition of life.

The failure of our theories, their ludicrous inadequacy to explain the facts, sets us thinking again, as we had forgotten to do. "Hypotheses," said Goethe, "are the cradle songs with which the teacher lulls his pupils to sleep." We survey the world of life and the evident course of evolution. We see that it is a *positive* thing; to account for it by a negation like natural selection, which explains the absent but not the present, is simply to be muddle-headed. And we may remember that one of the world's greatest poets described the living process in his own way, about a century ago. For, in his "Adonaïs," Shelley bids us see how

> The one Spirit's plastic stress
> Sweeps through the dull, dense world, compelling there
> All new successions to the forms they wear.

Here is the idea of life as something purposive, and therefore psychical, behind matter, striving through matter to multiply, to magnify, to intensify itself.

The Consciousness of Man the Intensest Form That Life has yet Reached

These lines were quoted by the present writer in his lectures on "Biology and Progress," at the Royal Institution, five years ago, as expressing the idea of itself which life gives us when we survey the living world. This is exactly the theory of Bergson, that life is a psychical thing, tending to act on and inform inert matter, and "compelling there all new successions to the forms they wear." Bergson does not quote Shelley, but he should certainly do so. The poet's lines express to a nicety what the French thinker describes as the *élan*, the thrust, the impetus, the "plastic stress," indeed, of life. The same conception occurred to the writer when he argued, in the lectures referred to, that progress is essentially "the emergence and increasing dominance of mind in the living world," and that it springs from the inherent tendency of life to express itself in ever intenser forms—the consciousness and self-consciousness of man being the intensest expression of life we can conceive.

Life Always Trying and Shaping for the Better

We must make a fresh start, then, with our theory of evolution, beginning with a conception of life as "of the psychological order," as something which, ike our own selves (who are simply its highest expression), has purpose and intention, goes on, is never satisfied, "never is but always to be blest." It is essentially creative, then, as Bergson expresses in his phrase "Creative Evolution," and as Shelley expressed by the word "plastic." Like any human practitioner of the "plastic arts," it makes models which are worthless and are destroyed, but it also makes good models which persist. Yet it is never content, as if it were merely "the continuous adjustment

of internal to external manifestations." As Bergson says: "Life in general is mobility itself; particular manifestations of life accept this mobility reluctantly, and constantly lag behind. It is always going ahead; they want to mark time." Is it not so with human institutions made by life acting through great men?

Hence the individual living thing, as a manifestation and vehicle of life—the onward "is above all a thoroughfare," even though too often "what was to have been a thoroughfare has become a terminus." The reader will observe that these phrases of Bergson's exactly consort with what we have previously argued as to the construction of the individual essentially for parenthood, and with Weismann's view as to the essential relation between the individual and the race—between the particular manifestation of life, and life itself. Are we not now, perhaps, on the way to some view of life which will explain for us the *origin of species*, that central problem of evolution, as to which Darwin's masterpiece told us nothing at all? It must be a view which conceives life as trying, as making efforts; and, as evolution maintains that man is part of the living world, our view must explain man with some greater adequacy than the theory of adaptation, and the "continuous adjustment of internal to external relations," when applied to, let us say, the men who leave their comfortable homes to find the Poles.

INTELLIGENCE IN THE LOWEST TYPES OF PLANTS

These minute, boat-shaped diatoms, without any visible means of propulsion, glide slowly in a straight line; and should anything obstruct their passage they retreat apparently on the same straight tract, often repeating the movement several times, as if unconvinced that the path was unpassable.

But surely the view of evolution which these arguments suggest is not entirely new. Have we not heard something like it before? Indeed we have, in the teaching of Lamarck. That great pioneer, still far too little appreciated on this side of the Channel, taught that living beings develop and modify their powers and their structure in consequence of their effort. Function comes first—life comes first—and develops structure for its purposes. Many neo-Lamarckians to-day follow their master in this respect. Yet how limited the action of effort and purpose, thus understood, must be! As Bergson says: "If this cause is nothing but the conscious effort of the individual, it cannot operate in more than a restricted number of cases—at most in the animal kingdom, and not at all in the vegetable kingdom. Even in animals it will act only on points which are under the direct or indirect control of the will." Hence, as he argues—and the reader will see how our theory of life can enlarge the idea of Lamarck so as to include all living forms—"A hereditary change in a definite direction—such as the evolution of the eye—which continues to accumulate and add to itself so as to build up a more and more complex machine, must certainly be related to some sort of effort, but to an effort of far greater depth than the individual effort, far more independent of circumstances, an effort common to most representatives of the same species, inherent in the germs they bear rather than in their substance alone, an effort thereby assured of being passed on to their descendants."

Thus, as we see, we have returned to the idea of the *élan vital*, the original impetus or thrust or effort of life, a thing essentially psychical, which passes from one generation of germ-cells to the next, through the developed individuals that bear them, and that is the *fundamental cause of true variations*. This is Bergson's theory, expressing Lamarck's idea, but enlarging it so as to apply to all living forms, and teaching us that the effort which we easily see in

animals, though not in plants, is really only the most intense expression of the original effort of life, which is in some degree in all living creatures. And if we duly weigh and consider this theory of Bergson we shall see that it should more properly be called the theory of Shelley, who gave it exact and scientific as well as poetic expression in the year 1821. This is one more instance of the triumph of poetic insight.

The fundamental cause of true variations, then, is the "plastic stress" of the "one spirit" which we call life, which, according to Bergson, is, "above all, a tendency to act on inert matter," and which, as Shelley said, "sweeps through the dull, dense world, compelling there All new successions to the forms they wear." Whatever we shall hereafter learn from Mendel and Bateson, of the mechanism and detail of heredity and variation, we must retain this great idea, which expresses the causation of variations, *and therefore of organic evolution*, which, as we know, absolutely depends upon the production of variations.

Two great questions remain, each of which has been dealt with by Bergson in masterly fashion. First, we must try to sketch out the lines along which the *elan vital* has worked and expressed itself, not least with reference to the question of man's destiny; and, second, we must go back to the old idea of a plan given beforehand which evolution is simply realising, and see why Bergson is entitled to argue that the new theory transcends altogether the old doctrine of a preconceived plan.


DESIGN IN NATURE—ONE OF THE ANTENNÆ OF A GNAT MAGNIFIED

We have only to look at the living world to see that life has adopted various methods of expressing itself. We can trace in the vegetable world characters which somewhat pertain to animals, and conversely. We can trace signs of intelligence in animals and of instinct in man. But, on the whole, there are very evidently divergent directions in which life has evolved, and a general survey of the living world displays them at once. The great point is that we are not to look at them, as we have done hitherto, as successive, but as divergent, each being an expression of the original characteristics of life.

Here are Bergson's own words—the italics are his:

"Vegetable torpor, instinct and intelligence—these, then, are the elements that coincided in the vital impulsion common to plants and animals, and which, in the course of a development in which they were made manifest in the most unforeseen forms, have been dissociated by the very fact of their growth. *The cardinal error which, from Aristotle onwards, has vitiated most of the philosophies of Nature is to see, in vegetable, instinctive, and rational life, three successive degrees of the development of one and the same tendency, whereas they are three divergent directions of an activity that has split up as it grew.*"

What is meant by "vegetable torpor" is quite evident. Plants are expressions of life asleep, so to say; not dead, any more than a sleeping animal is dead, but yet torpid and tending towards immobility, "the animal, on the contrary, becoming more and more awake and marching on to the conquest of a nervous system." Some writers have argued that it is the thick and rigid cellulose membrane of the vegetable cell that has shut it off from most possibilities of sensation, and involved its renunciation of consciousness.

Animal life has apparently been threatened in the same way. Early animals were imprisoned, too; the arthropods, or

joint-footed invertebrates, tended to form rigid cases for themselves. The earliest vertebrates, the primitive fishes, had hard, bony sheaths. But fortunately both arthropods and vertebrates escaped; the many forms remain to-day to show us how life might have remained at this humble level but for its inexhaustible impetus. The insects escaped from the arthropods, and the later fishes escaped. And if we trace these two forms we find in them the two great directions, instinctive and intelligent, in which life has evolved in the animal world. In each a nervous system appears and is developed in high degree. We can best judge of these two directions by looking at the most successful forms which life has taken in each. As regards the vertebrates and the line of intelligence, there is no doubt about man's dominance. He claims the entire earth for his domain, and is therefore the most successful form. His distinguishing mark is the unique development of intelligence in him.

If we apply similar reasoning to the insects there is no doubt either. Evolution in them (evolution of invertebrates generally) reaches its culminating point in those called the hymenoptera—the ants, wasps, and bees—just as evolution in the vertebrates reaches its culminating point in man. Hence, in Bergson's words: "Since instinct is nowhere so developed as in the insect world, and in no group of insects so marvellously as in the hymenoptera, it may be said that the whole evolution of the animal kingdom, apart from retrogressions towards vegetative life, has taken place on two divergent paths, one of which led to instinct and the other to intelligence." But just as rudiments of instinctive and even intelligent behaviour can be observed in plants, and just as animals are in constant danger of being drawn aside to the vegetative life—as we may have noticed—so instinct and intelligence tend still to cling together in some degree.

PLANT LIFE FEEDING ON ANIMAL LIFE
The leaf of the sundew is here shown feeding on a fly, the hairs turning towards the insect.

Thus, in almost all the vertebrates, though intelligence is there, instinct is the basis of their psychical activity, but intelligence tries to perform as many variations as possible on the instinct it would fain dispense with. "Intelligence gains complete self-possession only in man, and this triumph is attested by the very insufficiency of the natural means at man's disposal for defence against his enemies, against cold and hunger. This insufficiency, when we strive to fathom its significance, acquires the value of a prehistoric document; it is the final leave-taking between intelligence and instinct. But it is no less true that Nature must have hesitated between two modes of psychical activity—one assured of immediate success, but limited in its effects; the other hazardous, but whose conquests, if it should reach independence, might be extended indefinitely. Here, again, then, the greatest success was achieved on the side of the greatest risk."

Thus, life has taken many blind alleys, but only two or three highways; and of these, only one—that which leads through the vertebrates up to man—has been wide enough to allow free passage to the full breath of life. Only man the unlimited is on the open road. The reader will observe the exact consonance between this general theory of evolution and the characteristic facts of the body of man, which have been discussed in another section.

Now let us compare our conclusion with the alternative views which we have already referred to—the mechanical view, based upon the laws of chance, and the view that evolution has followed a plan. We must reject the first, and all the methods which assume its truth. As Bergson says: "Organic creation, the evolutionary phenomena which properly constitute life, we cannot in any way subject to a mathematical treatment." This conclusion of the philosopher goes far to explain what has

long puzzled the critics of "biometry," which has reached so many confident conclusions in the last ten years, but never one that further study has confirmed. The simple truth is that life is creative, and therefore immeasurable.

But what of the old idea of design—of evolution as simply conforming to a plan? The new theory, which utterly rejects the mechanical view, does not wholly reject this view, because it recognises the palpable evidences of design, in which the living body is far richer than any watch. But there is a very great difference between the old view and the new one. Just because life is creative, the direction of its action is not predetermined. It has purpose and intention, but no ready made plan. It is so with the products of life.

A man sits down to create or produce a play, called "Hamlet." It is not evolved by "natural selection," but by conscious purpose. But yet it is not merely the realisation of a plan. If Shakespeare had the complete plan when he sat down, then he would have produced "Hamlet" before he produced it, which is absurd. It is so with every creative product of man, or of Life, which includes man. It aims at "more life and fuller," at greater intensity, greater success, but it is a creator, not an artisan. "Hence the unforeseeable variety of forms which life, in evolving, sows along its path." A plan is given in advance, but to survey the amazing variety of the forms of life is to see that evolution is a creation unceasingly renewed, its future overflows its present, and transcends comprehension or prediction by the intellect of man, which is itself only one of the products of life. In Bergson's magnificent words: "We shall not witness the detailed accomplishment of a plan. Nature is more and better than a plan in course of realisation. A plan is a term assigned to a labour; it closes the future whose form it indicates. Before the evolution of life, on the contrary, the portals of the future remain wide open. It is a creation that goes on for ever in virtue of an initial movement."

This is by no means all we have to say of Bergson; he will dominate our thinking for many decades to come. Meanwhile his work prepares us for our further studies, as to the evolution of the mental and moral attributes of man—so hopeless of inclusion in the mechanical theory of evolution; and also in regard to the study of variation, and the production of new forms of life. We shall find that adaptation has been much exaggerated in the last half century, and that the Mendelian study of inheritance provides us with plenty of new forms which show no superiority of adaptation, but are *tolerated* (as Prof. Bateson has lately put it) by natural selection, and owe their existence to the "plastic stress" of life.

ANIMALS TENDING TOWARDS VEGETABLE LIFE

The green-flies or blight so familiar on plants may represent animals that are being drawn aside to vegetable life. The greater number are wingless and inactive, and their methods of reproduction are reactionary

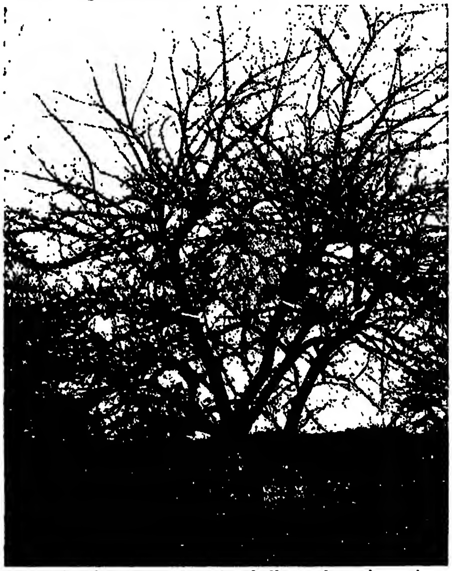
Meanwhile, we conclude by observing that science and philosophy are now evidently returning to the celebrated doctrine called Vitalism, which declared, a century ago, that life is an entity, not an abstraction, and we have seen cause to regard life as a psychical entity, to be included under Mind in our catalogue of the Universe. The best science and philosophy of the coming years are sweeping onward to Vitalism again, old but new. So true is it that knowledge grows not in a straight line, but in a mighty spiral. Those who crawl below, and do not care, may say that it merely retraces its steps, but they who will follow and further its flight know that the spiral ascends.

THE RIGHT WAY TO PRUNE APPLE TREES

An apple-tree in which the central leader, or branch, has been allowed to develop. Such trees are inclined to grow too high.

The open-centre habit of growth. A well-balanced tree, with plenty of room for the admission of light and air to all its parts.

A tree pruned from beneath, which costs too much to harvest the fruit.



The white lines on the branches indicate the points where the chief cuts should be made in pruning a tree of this kind.

The "loppers" used in cutting back higher branches

A ten-year-old apple-tree that has been neglected, not having had any of its branches pruned since it was planted.

The same tree as shown on the left after it has been pruned properly. The open centre for light and air is very marked.

METHODS BY WHICH TO SECURE THE MAXIMUM LIGHT AND AIR FOR THE FRUIT-TREE

THE TREATMENT OF PLANTS

Dwarfing and Shaping Trees and Opening Them to the Sun, with Cross Fertilisation and Transplantation

SURGERY AND MEDICINE IN THE GARDEN

We have now reached that stage in our consideration of the subject of plant life when it will be well to take stock of our ideas, because we are at what we may term the parting of the ways in our subject. That is to say, we are on the point of leaving behind the consideration of the general and fundamental principles upon which the science of plant life depends, and are about to turn our attention to the study of the more detailed processes which may be observed in individual species and families. These general principles are of the utmost importance. They must be thoroughly mastered before anyone can hope to obtain an adequate conception of what plant life is and does.

But the modern student of such a subject, if he would so utilise it as to make it of the greatest ease to himself in the widening of his conception of life as a whole, must go even further than this. The contents and arrangement of these pages have been purposely designed to meet this end. Those who have read the successive pages already issued cannot but have been struck with the great idea which the writers have endeavoured to present—namely, that the universe is one in itself, and that the greatest thing in it is life. For the convenience of study and description, this great problem of life has been subdivided into Life, Animal Life, and Plant Life ; and the point that we are at present endeavouring to impress upon our readers is that, in order to appreciate any one of these aspects thoroughly, the other two must be equally studied. In all these aspects of our study of life it was necessary to begin with very general conceptions before passing to the study of detailed instances, and so in this section, which is devoted to plants, we now find ourselves in this position.

We endeavoured to realise, in the first instance, that the soil itself, and all that it contains, was the foundation of our subject. So we studied its origin, its history, its composition, the food it contains, the bacteria that live and work in it, the marvellous and complex processes which these organisms carry out, the amazing potentiality of the soil, its preparation and cultivation, how these could be assisted by natural and artificial manures, and, finally, the problems connected with seed-time, seasons, and harvests.

All these are great questions, having fundamental principles behind them bearing upon plant life. Now, as we have said, we have come to the parting of the ways in our subject, and are about to devote our attention to more detailed topics. It is well, however, at this point to have mentally reviewed for a moment or two the steps we have taken to arrive at our present position.

Man, having entered into the heritage of the plant world, was not long before he ventured to endeavour to improve upon the natural conditions, as he found them, by artificial measures derived from his own fertile brain. He observed that if plants be left to themselves some perish in the struggle for existence, because they cannot compete with the virility of those around them. In the absence of weeding and tillage, and so forth, none but the strongest could flourish, and they only at the expense of their weaker neighbours. But amongst these plants which so perish, or which would do so under such conditions, were a great many whose beauty of design and form and colour, or whose value from the point of view of foodstuffs, made them eminently desirable to retain. Man, therefore, set his brains to work, and the result was—artificial cultivation.

To what perfection this has attained nowadays our following pages will to some

slight extent show, especially as regards the processes which man has devised. These processes are not, however, restricted to the treatment of the soil in which the plant lives, important and complicated as that is, but have been carried actually into the region of the treatment of individual plants themselves. In fact, there is nowadays in all modern agricultural lands a system of medicine and surgery in connection with plants as well as animals. We say medicine and surgery advisedly, because these artificial processes involve the use—just as is required by the human doctor—of both drugs and knife. The former are widely used as preventive measures in the case of threatened attacks upon plants by bacteria and other parasites. They are applied in the form of sprays and washes, and so forth, some of which we shall study on a later occasion in connection with plant diseases. It is with the latter—namely, the use of the knife—that we are at present concerned.

This subject of the surgery of plant life is an intensely interesting one, because it is not exactly on all-fours with that seen in connection with animals, a remark that brings before us a difference in plant and animal constitutions which must be emphasised at the outset. It is a biological point of the greatest importance, one that those who are studying life in its various aspects should endeavour to grasp, and of which the significance must be realised.

In the case of any of the higher animals, when once they have attained their full growth or adult maturity, no new parts or organs are added to the body. That is the law of growth for the animal. It is a very strictly defined one. In any good species it is so definite that it can be stated in figures for the individuals comprising that species. Thus the anatomist, the physiologist, or the comparative pathologist could tell us at once the average size and weight of the heart, the liver, the lungs, the kidneys, the spleen, and so forth, for all higher mammals. He will also tell us that if any of these organs, or a limb, such as a forearm or a leg, be cut off *it will not grow again.* The possibility of transplanting, in adult species, one part of the body to another in higher animals is strictly limited. True, a certain amount of skin can be so transplanted, and this is an extremely useful proceeding in certain cases. But it is quite impossible to transplant a leg or an arm from one of the higher vetebrates to another. It will not grow. Not only so, but the removal of any considerable portion of animal tissue in a mammal is followed, at the best, by a process of healing which does not in any way replace that which was lost. It is merely protective.

FRESH SHOOTS SENT OUT FROM THE ROOTS OF A TREE THAT HAS BEEN CUT DOWN

In the plant world all this is different, and it is upon this difference that what we have termed the surgery of plant life depends. During a recent storm of exceptional violence the writer observed an ancient tree, of perhaps a hundred years old, shattered and broken, leaving nothing but a wrecked stump. To all appearances it was a total wreck, a mass of hopeless destruction. The thick foliage which had

THE POLLARD WILLOWS THAT LINE THE STREAMS AND RIVERS OF ENGLAND

cast a welcome shade over the passing thoroughfare was drying up and dying, and already the boughs and branches were being sawn into convenient lengths for purposes of firewood. It was as if an animal had been blown to atoms by a cannon-shot, leaving nothing but its head or its feet. Had it been such a creature there would have been nothing for it but a decent burial. But it was a plant, not an animal. The plant surgeon knew that, so far from the life of the old tree being destroyed, all that was necessary was to trim the broken wounds by the application of saw and axe, and to wait in patience until next spring, when—marvellous as it is to think of—fresh life would penetrate the wrecked and shattered trunk, and evidence itself in fresh green shoots. In yet another year these would themselves give off lateral branches; and in some eight or ten seasons the glorious crown of foliage would once more rise over the warrior's trunk.

WILFUL INJURY TO A BEECH-TREE, AND THE NEXT YEAR'S EXUBERANCE OF SHOOTS BELOW IT

This simple illustration of an everyday occurrence will impress upon us the fact that there is hardly any limit to the operations which the plant surgeon, or head-gardener, may attempt without risking the life of his patient. He has learned this fact, and hence he hesitates not to cut and prune wherever experience has taught that it is advisable; and not only so, but he will venture to tear a plant—with all due gentleness—from its hold in

the earth, and even to apply the knife to its very roots, replanting it in perhaps a different situation. Such is the tenacity with which plants hold that mystery of life which enables these things to be done.

Doubtless it was the observation of some such fallen tree springing into new life—as described above — which led the primitive agriculturalist to devise the various methods of pruning that have been in existence for a very long time. It would be observed that branches which were broken off, or twigs that were shed, were in due time replaced by others, and thus would arise a belief that surgical interference with the structure of parts of a tree might be pushed to almost extreme limits. The new growth that follows such amputations is developed by means of the buds in the stem which have been lying dormant all the time. Upon their existence depends the whole success of the operations of pruning in all their phases.

HOW TO CUT UPRIGHT BRANCHES

In heading back upright branches the cut should be made just beyond a branch extending outwards as shown here.

7886

Pollarding is another example of an analogous operation. Pollard trees are kept cut down to a particular altitude; and the result of this is that a copious and plentiful outgrowth takes place just below the level of the section. Examples are frequently seen in the case of willows. Vines are sometimes treated in a similar manner, and so are a great variety of fruit-trees. All operations of this particular kind have the same object in view—namely, to promote the growth of an increased number of more vigorous branches from the stem which is retained, or to increase the harvest of timber in the case of forestry, or fruits, as desired. In fact, by varying the position of the operation it is thus found possible to produce almost any kind of shape of tree desired. Hence the weird examples sometimes found in gardens in which the evergreens have been pruned to outline the shapes of birds and beasts.

A NEGLECTED WOUND

Decay starting at this point has extended far down the trunk. Large wounds like this should be well coated with paint

It must not be supposed, however, that identical methods of pruning will produce the same results on all plants and all trees; indeed, this is very far from being the case. Different species of trees and shrubs have their own particular growth in connection with the dormant buds from which the new branches arise; and it is for this reason that experience has shown that it would be ridiculous to pollard an apple-tree, as is done to the willow, or to attempt to produce a thick undergrowth in a forest by means of pines. The natural habit of the growth of the individual tree must be taken into account when the method of its pruning is considered. Climatic influences also have a bearing upon this point, an excellent example of which may be seen in the various modes of pruning in the vineyards of different countries. Thus that employed in Hungary differs from that on the Rhine, as does the latter from that in northern Italy, which, again, is quite distinct from the methods practised in the south of that country.

Of all these surgical interferences in the treatment of plants, pruning is the one to which we may pay most attention at this stage; and, since it is always well to be as concrete as possible, we may consider it in connection with the tree which will be found wherever these pages are read, and which will therefore offer familiar examples of what we say. That tree is the apple-tree. This fruit is of such immense commercial importance, and is such a common article of diet, and has had, moreover, such immense attention paid to it in this very matter of various methods of propagation, that one could not select a better example for our purpose.

It would be a mistake, however, to think that there is unanimity amongst the recommendations of the various authorities

HOW TO IMPROVE THE APPLE HARVEST

A 13-year-old apple-tree injured by leaving fillers in the orchard too long, characterised by long upright branches.

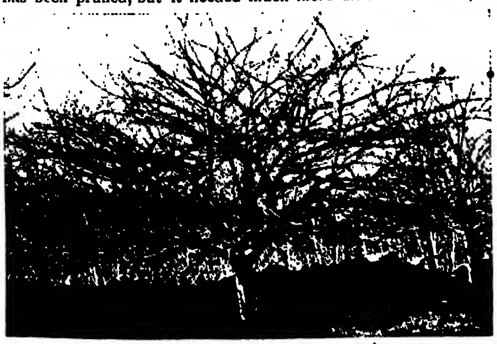
A high-headed tree. If such trees are renovated they should be severely headed in, as indicated in the picture by the curved white line.

A well-shaped tree. This tree was grown in an orchard without fillers. It should be compared with the first in this row.

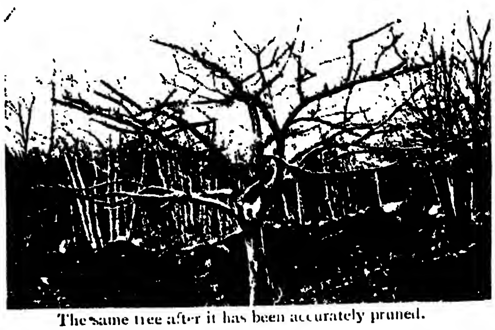
Long-armed trees. The result of close planting. Half the trees should be removed and the remainder headed in, as marked.

The first year's growth after the renovation of some old, high-headed trees. The proper treatment for the trees shown on the left.

The left-hand picture shows a high-headed tree badly in need of repair; in the right-hand picture the same tree is shown after it has been pruned, but it needed much more drastic treatment, and should really have had the top removed down to the white mark.



A good type of apple-tree for renovation.

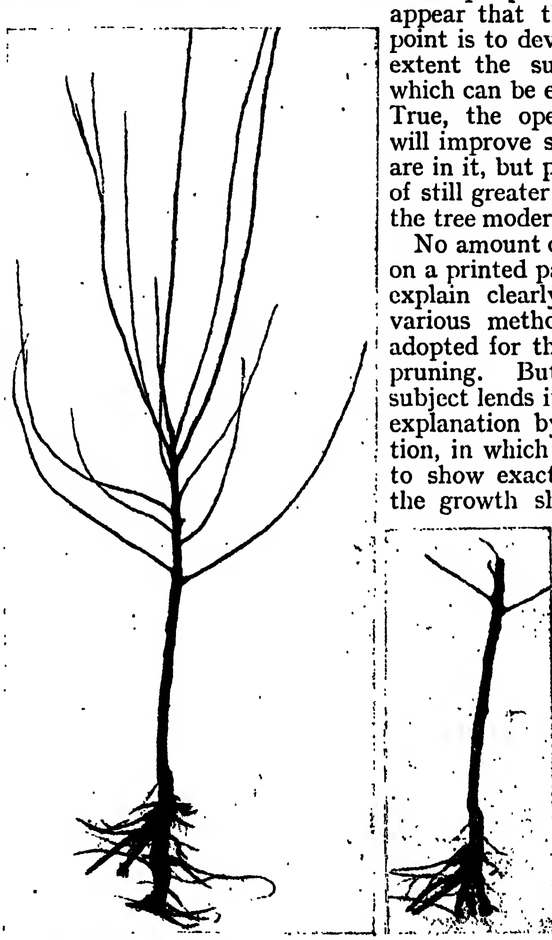


The same tree after it has been accurately pruned.

THE RIGHT AND THE WRONG METHODS OF IMPROVING THE YIELD OF APPLE-TREES

as to regular pruning methods. On the contrary, there is a good deal of difference of opinion. That is partly because of the different conditions which obtain in various regions of the world, and also because of what we may term the individuality of trees. These factors have given different results to different experimenters, and hence the fruit-grower may have some difficulty in deciding upon his procedure. Trees which are growing rapidly and strongly must be treated upon different lines from those exhibiting a weaker tendency; and those which are obviously endeavouring to shoot straight upwards will require treatment other than that which would be applied to growth tending laterally. Then, above all, the fruit-grower must have in his mind a picture of an ideal tree such as he wishes to produce, and upon this model his pruning operations.

In connection with the apple-tree, a great deal of experimental work on the subject has been done at the famous Storr's Agricultural Experiment Station in Connecticut. From these experiments we would deduce the following conclusions:



A TWO-YEAR-OLD NURSERY TREE BEFORE AND AFTER PRUNING

The difficulty of harvesting fruit from high-headed trees, as compared with low-headed trees, is about 25 per cent. of the crop in favour of the latter, which are, moreover, much more easily sprayed, and more conveniently pruned and trimmed. In addition, other things being equal, the lower trees are less liable to injury from wind. For these reasons chiefly the tendency at the present time is to prefer low-headed trees.

Then comes the question of the shape of the tree itself, and this is particularly concerned with the advocacy of the type of tree with *the open centre*. The object of this method of pruning is, of course, to allow of the free access of sunshine into the middle of the tree, and hence to produce more fruit of a better colour and richer flavour. But, after all, the greater part of the fruit is not borne in the centre of the tree, but at its periphery, so that it would appear that the most important point is to develop to the utmost extent the surface of the tree which can be exposed to the light. True, the opening of the centre will improve such apples as there are in it, but probably it would be of still greater advantage to open the tree moderately on all sides.

No amount of verbal description on a printed page can be made to explain clearly to a reader the various methods which may be adopted for the various stages of pruning. But, fortunately, the subject lends itself very readily to explanation by means of illustration, in which it is perfectly easy to show exactly what portions of the growth should be cut away for the production of trees of definite shapes and patterns. In these pages will be found a series of pictures that show with great clearness these operations, and convey much more definite information than any number of pages of print could possibly do. A careful scrutiny of them will show at once the principles upon which a decision is come to concerning the branches that are to be cut out, and those that should remain. It will be seen that the object in view is to produce a tree with branches as evenly distributed as possible, leaving plenty of space between them for the admission of sunlight and free access of air. How much should be removed and how much left, experience only can teach, because the appearance of a tree during the winter when the leaves are off gives a very deceptive

impression of the amount of its foliage, especially that carried by the smaller branches during the summer. It is for this reason that the most common error is the leaving of too much small wood. It is quite true that in so removing small branches the number of apples—or other fruit, as the case may be—may be somewhat reduced, but this numerical reduction is more than compensated for by the improved size and quality of those which are ripened.

When it is a question of determining which of two branches should be cut out and which left, it is better, as a rule, to retain the lower one. The two branches should be compared mentally as to their relative importance for fruit-bearing, spraying, gathering, and other processes. Especially should all the unsightly branches which cross one another in the middle of the tree be cut out, and, needless to say, any portions of dying or dead wood ruthlessly excised. In order to maintain an even shape it is necessary to prune back the rapidly growing young shoot at the extreme ends of the branches, and none of the sprouts which come up where the trunk enters the ground should be left.

The ultimate shape of the tree can be largely controlled by paying attention to the exact position and direction of the cut made by the operator. For instance, if it is desired that a branch should extend outward. the cut should be made at a point just beyond a bud, or another side branch which is already growing in the direction desired. Similarly, if the object is to induce a spreading branch to grow upwards, this object may be attained by the cutting back to a bud or other branch already tending in that direction. In addition to these operations controlling the ultimate shape of the tree, cuts which are made close to side branches heal up much more satisfactorily than those at a distance. The cuts in trees should be made quite close and parallel to the branch from which the removed portion is springing. If it be made too far away from a bud or branch the portion left is apt to die or decay, forming a point of entrance for fungi, which may ultimately result in the hollowing out of the trunk that one so often sees in an old orchard. In order to promote the healing over of the cut surface, it is customary to treat the wound with grafting wax or a coat of paint. As regards the special tools used by the operators for the different kinds of pruning, one need only say that they consist of either an axe, a saw, some pruning-shears, or what is sometimes termed a "lopper," this last implement being used to cut back the topmost branches of the tree. The next point to consider is the time of the year at which pruning should be done. According to the season chosen, slightly different results are obtained. Thus, if the pruning be done during the season when no growth is taking place, the result is the stimulation later of new growth of wood. On the other hand, pruning during the season in which wood is growing induces increased fruitfulness. Hence it is that both summer pruning and winter pruning may be adopted for various purposes. A tree

THREE FRUIT-BEARING LATERALS OF AN APPLE-TREE
The weight of the fruit is bearing down three lateral boughs and restricting the flow of the sap.

which has the habit of making too much wood and too little fruit may have this tendency checked by summer pruning. That is to say, the rapidly growing shoots are removed at the height of the growing season.

As regards the winter pruning, it is said by some that the early spring pruning heals up better, but, on the other hand, the fruit-grower has more time to spare in the late autumn and winter, and, as a matter of fact, usually does his pruning whenever the weather is favourable. More important, perhaps, is it to remember that it is better to do a certain amount of pruning every year than to allow the trees to grow in such a way that a heavy pruning is required at longer intervals. No hard and fast rules can be laid down for universal application, because no two orchards are precisely alike in their requirements. But the principles of proceeding in all cases are the same, and are those which we have here outlined briefly.

A TWELVE-YEAR-OLD TREE READY TO BE TRANSPLANTED

The medicine and surgery of plant life is, however, by no means confined to the application of drugs for the prevention of infection, and the use of the knife for the removal of dead portions or for the varied purposes of pruning. It goes much deeper into the mystery of life than any of these processes, because it is employed actually to produce types of plants themselves. In other words, the discoveries of plant physiology enable the plant doctor—so to speak—to interfere artificially at the actual moment of conception, and to produce, within certain limits, almost any kind of plant he likes. This process is what is termed "hybridising." Many of its aspects are dealt with in other portions of our chapters on Life, Animal Life, and Plant Life, and other aspects of it will be treated of in this section later, in connection with the detailed study of reproduction. Some preliminary statements, however, may be made at this stage when we are thinking of the artificial interference with the normal life of plants which man can successfully attempt.

The possibility of hybridising, of course, depended upon the establishing of the fact that in the plant world, as well as in the animal, the separation of the male and female sexes is a widespread occurrence. The significance of this evolution of sexes in animals has been argued in great detail on a previous page (see page 536), and we may state here that, without repeating what was there said, it seems fairly obvious that the advantage of the separation of the sexes in plants must be connected with the process of cross-fertilisation. By cross-fertilisation we mean the transferring of the pollen-cells from one flower to the stigma of another flower which contains the female germ-cells in its ovary. This may be done between plants of the same species, and also between plants of different species.

A MODERN METHOD OF CROSSING WHEAT
An anther containing pollen is suspended from the end of the forceps

It is in the latter case that we have the process of hybridising. By utilising the facts which have been observed, man has been able to produce, nay, actually to create, new crops such as we discussed in our last

chapter. One of our illustrations shows the actual process by which the operator is transferring in a small pair of forceps an anther containing pollen. In this case it is a wheat plant that is being artificially crossed. It was at one time thought, if the progeny of a cross turned out to be themselves fertile, this was sufficient to prove that the parents utilised were of the same species, whereas if the progeny were sterile the parents must have been of a different species. This test, however, of the identity of species has had to be abandoned as the result of experiments in recent years, because quite a number of crosses have been made between plants of different genera without interfering with their fertility. Some very curious crosses have been experimentally produced, and some of these among plants which differed widely in appearance. Thus the black-currant and the gooseberry have been crossed, as have been the flowering currant and the gooseberry, and wheat and rye. The first hybrid plant recorded was probably that of Fairchild's sweet-william, produced by a gardener of that name in 1719 by crossing a carnation and a sweet-william. Many other observers followed and performed numbers of experiments on similar lines, but it was not until Darwin published his great book on "Animals and Plants Under Domestication" that the science of hybridising was put upon a firm basis. An immense impetus has been given to it by the publication to the world of Mendel's experiments with peas, which will be fully dealt with elsewhere. Here our object is to emphasise from another point of view those things which the science of medicine and surgery as applied to plants is capable of performing. They could in this process of hybridising actually determine the kind of living organism that is to be produced.

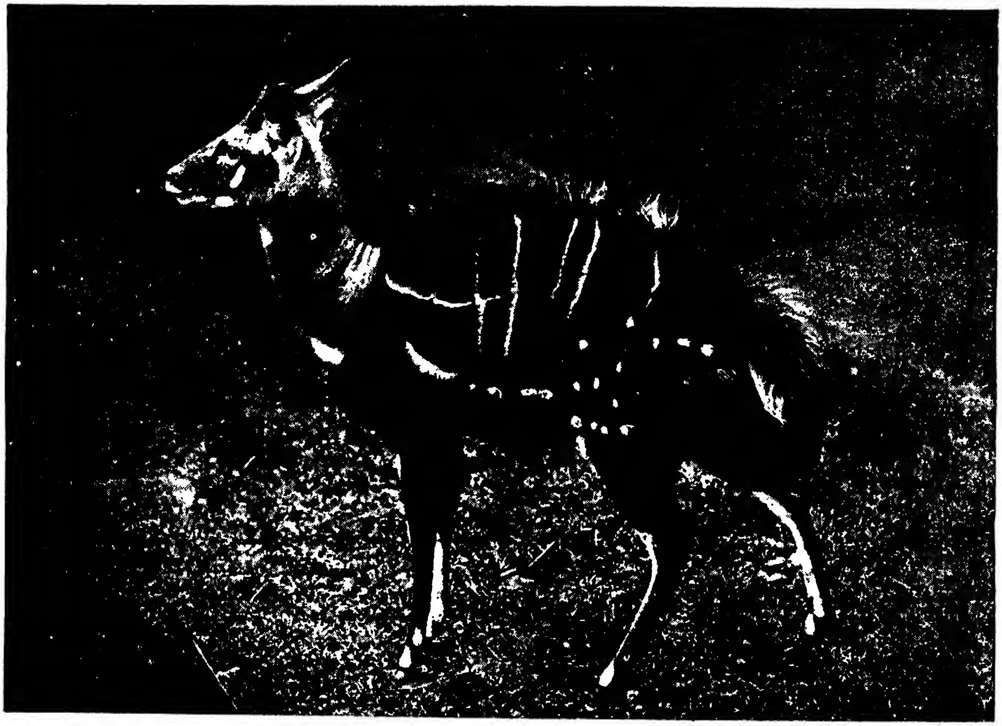
AN EXAMPLE OF NEW CREATION—THE LOGAN-BERRY, A CROSS BETWEEN THE RASPBERRY AND THE BLACKBERRY

But even that is not all. Not only can the plant physician determine the direction in which the plant life is to grow; not only can he—having grown the plant—proceed to operate and amputate in every conceivable direction so as to produce just exactly what shape of plant he desires; he can do more than this, because he can uproot the whole organism from its nutritional basis and transplant it into an entirely new environment. Indeed, the operation of transplanting is nowadays, in agricultural work, a routine procedure in the cultivation of many plants. By its means immense numbers of plants can be grown in a restricted area up to a certain size, and can then be pulled up and sent almost to any part of the world to be transplanted in new surroundings. And although this is easier to carry out in the case of small plants such as cabbages, yet it can be performed, if great care be taken, with very much larger growths. Quite a number of cases are on record where extremely large trees have been carefully uprooted, taken a considerable distance, and replanted with perfect success. It seems, indeed, as if there were hardly any limit to the extent to which the plant surgeon may interfere with the normal life of his patient, provided ordinary care be taken.

FIVE MEMBERS OF THE ANTELOPE GROUP

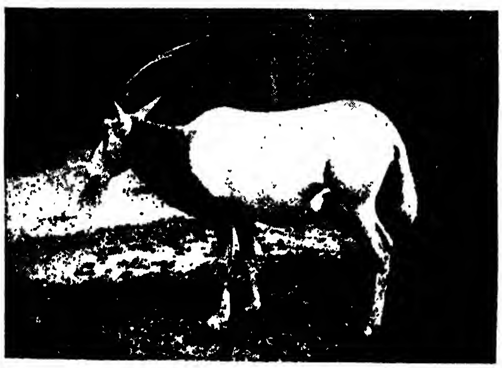
THE ANOMALOUS FOUR-HORNED ANTELOPE

A DENIZEN OF THE SWAMP—THE MARSHBUCK



A HARNESSED ANTELOPE, SO CALLED FROM THE CURIOUS HARNESS-LIKE STRIPINGS OF ITS COAT

THE SABLE ANTELOPE



A SABRE-HORNED ORYX

The photographs on these pages are by Messrs. W. P. Dando and Lewis Medland

THE ANTELOPE FAMILY

A Group of Animals Inhabiting all Uncultivated Lands from Jagged Mountain Tops to Sandy Plains

THE LINK BETWEEN GOATS AND CATTLE

At Kew Gardens an excellent scheme is carried out, whereby the visitor is able to see, growing side by side, gathered from many lands, all, or nearly all, the available species of the particular plant or tree in which he is interested. Now, if we could get together a really representative assemblage of all the animals which come within the limits of our present chapter, we could set the best of naturalists a stiff problem by asking where, on the one hand, the goats end and antelopes begin; and where, on the other hand, the antelopes end and the special cattle begin. The problem is a most difficult one. Step by step we are led on from the sheep and goats by the tahrs, the gorals, the serows, and the takins, and, sandwiched between these and the first possible genus of antelopes, the Rocky Mountain goat, we have—the musk ox; then, after the musk ox and the so-called goat, the chamois.

Antelopes are hollow-horned ruminants—that is to say, animals which chew the cud. Unlike the antlers of the deer, which, as we have seen, are shed every year, the horns of the antelopes are permanent growths. But oxen and sheep and goats are hollow-horned ruminants, too. Antelopes are none of these, obviously, so the rule observed in establishing the classification is, if an animal be a ruminant and possess hollow horns with a bony core, to relegate it to the antelope group.

It is not satisfactory, for we get the most diversified aggregation of animals imaginable. We have in one and the same group pigmy creatures no bigger than rabbits, and weighing about as little, and at the other end we have lordly beasts such as the eland, standing over six feet at the withers, and weighing up to 1500 lb. and more. Even with so elastic a grouping as this, there are left out the animals already cited. They take precedence of the antelopes, and, in the order given, each constitutes a separate genus of the bovine family. They are more or less closely allied both to goats and sheep and antelopes, yet we have, in the larger group, antelopes which are quite isolated from all other existing antelopes, the story of whose descent must be sought in the records of geology. Even with the denizens of the debatable land omitted—the tahrs, serows, and so forth—even without these, there remains a formidable array of animals for our group, numbering, with the Rocky Mountain goat and the chamois, seven sub-families and something like 150 species.

And what of these outlanders? The tahr, which is also called the Himalayan goat, and, as to one species, the Nilgiri ibex, differs so pronouncedly from the true goats that it is referred to a genus of its own, where it forms a genealogical stepping-stone between the goats and the antelopes. It is a forest-haunting animal found on the mountain sides. A stout, stocky beast, the male attains a height of from thirty-six to forty inches at the shoulder. The goral is a goat-like animal still nearer the antelopes, three to four inches less in height than the tahr, and having as its nearest ally the serow, a shaggy ruminant of South and South-Eastern Asia, larger than the tahr, haunting the forest-clad upper slopes of the mountains, a slow-moving beast on the flat, but splendidly agile among rocks, and courageous to a fault when danger threatens from any foe, animal or human.

The takin comes next in order of relationship, a powerfully built animal, with horns resembling those of the musk ox. It is a native of the almost inaccessible mountains of Eastern Tibet and Bhutan; and great was the rejoicing of zoologists when a specimen, the first ever seen in Europe, was

deposited in the London Zoological Gardens. Closer acquaintance with this animal has enabled naturalists more correctly to place the musk-ox, which has closer affinities with the takin than with the sheep and cattle, wherewith it was wont to be asso-

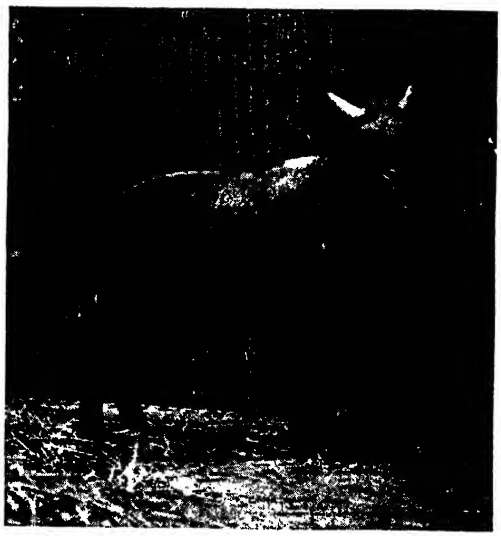
LINKING GOATS AND ANTELOPES—THE TAHR

ciated. Of course, the musk-ox is not to be regarded as an antelope, that is patent to everyone, but it is an ally of the takin, and, through the takin, of the serow and the goral, and so leads us back once more to the antelopes.

Both serows and takins are regarded now as related to the Rocky Mountain goat, the first of these animals from the naturalist's terra incognita to be admitted definitely within the pale of the antelope family, goat though we call it. It is short and heavy-limbed, and not particularly alert, depending for the avoidance of man upon its powers of concealment in the shadow of boulders and rocks rather than upon speed. This animal developed when America was so sparsely peopled that man did not give it occasion to make a high speed necessary; and it is a fortunate fact that, with cheaper materials on the market for blanket-making, the animal is not now so valuable to the hunter, and thus has the opportunity peacefully—in parts of its range, at all events—to renew its depleted numbers. It would be interesting to see what a first-rate sheep-breeder would evolve from the Rocky Mountain goat. It would start fairly, possessing as it does a thick coat of wool beneath its longer outer covering of hair.

The chamois are the last of the goat-like animals included among the antelopes. They are so included, be it noted, though never without demur. Although these animals are regarded as peculiar to the Swiss Alps, the fact is that they are common to the mountains of Europe and Asia Minor. The species identified with the first mentioned locality has been persecuted in some districts by sportsmen almost to the verge of extinction, and it might now fairly share the protection the Alpine eagle is to enjoy.

All species of chamois agree generally in habits. The majority of them keep close to the woods with which the mountain sides are clothed, and it is only the few, and not the generality, which at certain seasons of the year betake themselves to the higher, more exposed ranges; and these return with speed to the protection of the forests when inclement weather comes. Within the shelter of such retreat the larger number of animals remain all the year round, and are known as wood chamois, to distinguish them from those of wider range, which are termed glacier chamois. The food of all consists in the main of lichen and scanty mountain herbage, a diet from which they manage to extract nourishment sufficient for strength and beauty and climbing powers excelled by hardly any other animal.



A NEW-COMER TO EUROPE—THE TAKIN

A good buck may weigh from 50 to 70 lb., yet he will scale the dizziest peak and stand poised upon a pinnacle with all four feet securely placed, though the space occupied could be covered by a crown-piece. So now to the antelopes proper, the

parent stock, it is believed, of the more specialised cattle and goats. The eland heads the list, but as this animal has already been mentioned in an earlier chapter we need refer here only to an interesting fact as to its capture noted by Herr Hagenbeck. The adult animals, for all their weight and size, are too speedy and enduring, unless excessively fat, to be captured on horseback, though, of course, they can be shot. It is the young eland that the hunter must run down. These can be cut out of a herd by a well-mounted man. As soon as it is captured its hind legs are tethered, the animal is swathed in a warm rug, and a subcutaneous injection is administered. This throws the young eland into a profound slumber that lasts nearly twenty-four hours, and at the end of this time it is ready to accept a milch cow as foster-mother. These precautions are necessary from the fact that after a chase the young animal is thrown by exertion and terror into a profuse sweat, and, unless treated in this manner, a reaction, accompanied by rapid lowering of temperature, follows, with the result that the animal dies in the course of a quarter of an hour from acute exhaustion.

One of the distinguishing features of the antelopes is the fact that horns are borne, as a rule, only by the males, yet of the first

AMERICA'S ANTELOPE—ROCKY MOUNTAIN GOAT

three genera, the elands, the bongos, and the kudus, the first and third are exceptions to such rule, though, of course, the appendages are smaller in the females than in the other sex. The bongo is a large and powerfully built animal, the adult bull standing about four feet at the shoulder, and carrying horns measuring thirty-five inches in a straight line. It is a forest-haunting antelope, but the handsome kudu, which is still larger, reaching as much as fifty-two inches at the withers, with horns four feet in length, is

A KING OF THE ALPS—THE CHAMOIS

less restricted in its range. It is equally at home in the dense thickets of broken hill-country and the tangled scrub and thorn jungles of lower levels. Blessed with wisdom enough to flee, when pursued, to the highest and roughest part of their range, these antelopes make their pursuit extremely difficult to the mounted hunter, even if he be prepared to brave the terrors of the tsetse fly, whose bite is fatal to the horse.

The term "harnessed antelopes," with which we frequently meet, embraces three distinct species, the nyala, the bushbuck, and the situtunga, or nakong, commonly known as the marshbuck. The genus is confined to Africa, but has its Oriental representative in the Indian nilgai. The nyala haunts the low-lying, fever-ridden swamps of South-Eastern Africa, and so enjoys relative immunity from the light-hearted persecution of the European sportsman, who has done so much in our generation to divest Africa of some of the chief glories of her fauna.

The bushbuck, which is smaller than the nyala, ranges from Abyssinia to the Cape, with many interesting variations according to locality. The marshbuck keeps to marshy areas, and varies so much with its habitat that only by the strictest vigilance have naturalists repressed the tendency to term

many of these varieties new species. The differences are mainly as to size and coloration, but one cardinal point of resemblance outweighs all the distinctions, and that is in the interesting modification of the hoofs of all marshbuck, which are enormously lengthened to suit a life spent upon a clinging boggy surface, and the negotiation of masses of drowned or floating vegetation.

The whole study of the hoofs of antelopes is profitable and suggestive. The hoofs show surprising variation, or perhaps it would be more correct to say that surprisingly different results are attained from the variations which present themselves. The hoofs of each species, or genus, are beautifully adapted to the special circumstances of the animal's life, whether that life be passed among precipitous rocks, in treacherous bog, or the loose yielding sand of the desert. We have here surprising examples of the adaptation of quadrupedal equipment to environment, and while the foot of the desert antelope leaves the camel owner marvelling, the klipspringer's feats, achieved with such tiny hoofs, reduce the hardiest human mountaineer to despair.

Although, as we have seen, the nilgai is the Oriental representative of the harnessed antelope, it is known in its native land as the "blue bull," or blue ox, such being the English of the name by which it is familiar to us. This animal is remarkable among antelopes from the fact that its fore-limbs are longer than the hind pair, so that the height of the withers, expressed in figures, gives an erroneous impression of the animal's size. The colour of the bull is a dark bluish-grey, hence its name, and its height may vary from fifty-one inches to as much as fifty-eight inches. Fossil deposits show that the nilgai once had a far more extended range than it now enjoys, for at present it occurs only within a well-defined area in India. Seeing that it carries insignificant horns, that its flesh is unpalatable, and that firearms have nullified the value of the shields formerly made from its hide, this antelope should have a very good chance of continuing in abundance, for its economic value is small. But there is the game hunter, of course, and the nilgai is a dear prize in his vain and wanton campaigns.

THE SUPREME DEVELOPMENT OF THE ANTELOPE—AN ELAND COW WITH HER CALF

We pass next to an interesting antelope, the chousingha, or four-horned antelope, an animal restricted to thin forest land at the foot of the Himalayas. This animal, as its name indicates, has for some remarkable reason, which it is impossible now to fathom, developed a second pair of horns, the larger pair placed far back, the second and smaller being immediately over the eyes. We find horns of a very different type in a group of antelopes in which the addax heads the list. In this group the horns are long and cylindrical—in both sexes—and either

straight, spiral, or curved. The addax interests us from its isolation from kinship with all existing antelopes. Far, far back in time, the genus, which consists of only one species, branched off, it is believed, from the gemsbok, betook itself to the desert, whence it has never budged, having perfectly mastered the problem of maintaining life for long periods upon a scanty diet when water, so far as man is able to ascertain, is absent.

Another desert-dweller is the gemsbok, a big antelope with horns attaining a length of nearly forty-eight inches in the male, and as much as forty-five in the female. The horns of the beisa oryx, though shorter than those of the gemsbok, are very formidable, and it

NILGAI ANTELOPES IN THE SNOW AT HERR CARL HAGENBECK'S PARK, STELLINGEN, NEAR HAMBURG

is a point still in dispute whether it was this animal or the white rhinoceros which gave rise to the legend of the unicorn. So far as bodily outline is concerned, the beisa undoubtedly has it, but then it possesses two horns. As to this there is to be noted the fact that a beisa, seen sideways, does appear to have only one horn, and the man who first saw one of these animals so posed might not be concerned to tell of the later view presented, for to do so would spoil a traveller's tale.

The beisa oryx, with the Arabian oryx and the white oryx, is restricted to country termed barren, but which the existence of these animals proves to be intermittently fertile. The fact is, much of the African desert is not desert in the sense ordinarily understood. Deserts support an abundant fauna, and it is there that the lion prowls in quest of such animals as we are at present considering. Apart altogether from the oases which, as operations in Tripoli have recently reminded us, are often of very considerable extent, desert conditions vary from swift and transient fruitfulness to the dreary sterility of appearance wherewith the popular conception always associates them. We need not go beyond Mr. H. A. Bryden's description of a season of fertility in the great Kalahari desert. "During the brief weeks of rainfall," he says, "no land can assume a fairer or more tempting aspect. The long grasses shoot up green, succulent, and elbow-deep; flowers spangle the veldt in every direction; the giraffe-acacia forests, robed in a fresh dark green, remind one of nothing so much as an English deer park; the bushes blossom and flourish; the air is full of fragrance; and pans of water lie upon every hand. Another month, and all is drought; the pans are dry again, and travel is full of difficulty." But though apparently vegetation perishes from off the face of the earth, the soil teems with bulbous moist roots, that form a nourishing diet for antelopes, and a desert melon is a favourite item of food.

It is a fact that some of the finest of all antelopes exist in the desert, and thither predatory animals have pursued them. The

existence of antelopes, among other living creatures, obviously modified, both as regards hoof and protective coloration, is cited as an evidence of the antiquity and permanence of deserts. The reasoning on this head is not absolutely conclusive. The modifications of the antelopes may have taken less time than we suppose. Adaptability is not necessarily a process of æons. Herr Hagenbeck is not the oldest man on earth, but he has antelopes and ostriches, lions, Bengal tigers, and kangaroos running at large in the snow every winter at Stellingen, not a penny the worse for their exposure. But, whatever the date of the arrival, there are the antelopes of the desert to-day specially armed to resist carnivorous enemies, no less than for combat, antelope versus antelope.

THE AGILE KLIPSPRINGER

Darwin wondered whether the horns of some of these splendid creatures might not, like the most complicated of antlers, have a decorative as well as defensive object. Whatever the case as to that, there is no doubt as to the deadly effectiveness of the weapons, for antelopes of this group are known at times successfully to counter the onslaught of the lion. At such a time the antelope kneels with its head between its forelegs, and at the psychological moment brings up its horns with a lightning swing, which means death if the blow goes home. We know that the blow is lethal from the fact that a lion has been found dead, impaled upon the horns of a dead oryx. Gentle even to timidity in normal conditions, these antelopes will at certain times, and especially when wounded and bayed, charge man or dog with boldness and ferocity.

THE PIGMY DIK-DIK

The Royal Buckhounds learned to respect the flashing accuracy of the red deer's hoof, even such deer as had often been submitted to the absurd barbarism of carting and hunting, but when we come to big, heavily horned antelopes like the roan and sable, we have two warriors which match the gemsbok in the potency of their defence. There were three species to this genus, but the blaauwbok, as the Boers named the bluish-coloured animal, has been removed from the chapter of the living, and only the sable and the roan remain. The former is the finer of the two species, but both are noble-looking animals, and Mr. Selous has seen the sable buck, when wounded, turn, and with three well-directed blows kill as many dogs with its terrible horns. Neither sable nor roan antelopes are numerous, wide as is their range, for a head of either is a trophy of the chase which every hunter in Africa seeks to acquire.

Passing now to the gazelles, we reach a great group of animals classed with the antelopes, from which they differ, however, in that horns are present in both sexes. These horns, often ornate and decorative, are turned to good account against the smaller predatory animals, for even the "dear gazelle," so famed for its gentleness and beauty, will fight gallantly when pressed, and join, buck with buck, to oppose as solid a phalanx to the common foe as the larger animals of the bovine family. That, however, applies only to animal foes, for, even as the Red Indians learned in time to look with terror upon the white man and his "medicine" methods of warfare, so the gazelles, in common with the rest of the antelope tribe, will always flee a man's face, unless it be brought actually to a standstill.

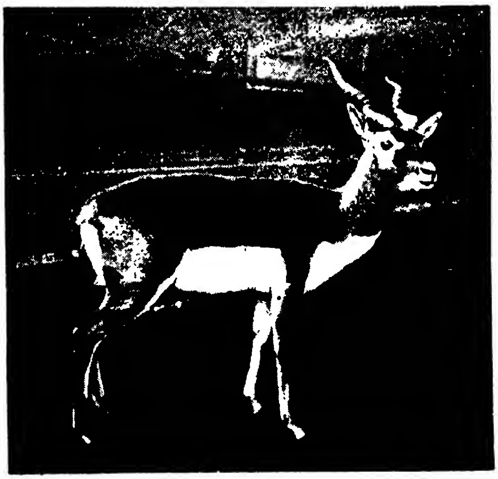
It is impossible to more than glance at this group, mentioning by the way that the general colour-scheme is light sandy, and that the face is, as a rule, distinguished by two stripes of contrasting colours—one a dark brown line passing from the eye to the curves of the mouth, and the other a white line, reaching from the base of the horns practically to the muzzle. The spring-buck, whose name first comes to mind at the mention of the gazelle, is a biggish

THE ANTELOPE IN SIX VARIETIES

THE RED-FRONTED GAZELLE

THE EGYPTIAN GAZELLE

THE AFRICAN SPRINGBUCK



THE INDIAN BLACKBUCK

THE SING-SING WATERBUCK

THE ROE RHEBUCK, OR RHEBOK

member of the group, its height, thirty inches in the adult male, equalling that of some Shetland ponies. Springbucks once abounded in South Africa in almost incredible numbers, and their annual migrations, with Brehm's stirring description of which most of us are familiar, recalled the march of the multitudinous hosts of lemming.

These migrations were thought by Livingstone to result from the fact that in the Kalahari desert, at a season such as we have been contemplating, the grass becomes so tall as to prevent the springbuck from seeing the surrounding country. Brehm, however, attributed them to the drying up of pools and the disappearance of vegetation. Whatever the exciting cause, the multitudes of springbucks mustered on the march before indiscriminate slaughter reduced their numbers simply beggared description. Converging upon one route, flocks became herds, the herds armies, resembling the swarms of locusts that darken the sun. "In the plain," Brehm noted, "they cover square miles, in the mountain passes they throng together in a compact mass which no other creature can resist. Over the low grounds they pour, like a stream that has overflowed its banks and carries all before it. Bewildering, intoxicating, and stupefying even the calmest of men, the throng surges past for hours, perhaps days together. Like the greedy locusts, the famishing animals fall upon grass and leaves, grain and other fruits of the fields; where they have passed not a blade is left. The man who comes in contact with them is at once thrown to the ground; a flock of sheep feeding in their way is at once carried off, never to be seen again; a lion which thinks to gain an easy prey finds himself forced to relinquish his victim and to travel with the stream. Unceasingly those behind press forward, and those in front yield slowly to the pressure; those cooped up in the centre strive continually to reach the wings, and their efforts are strenuously resisted. Above the cloud of dust raised by the rushing army the vultures circle; flanks and rear are attended by a procession of various beasts of prey; in the passes lurk sportsmen, who send shot after shot into the throng. So the tortured animals travel for many miles, till at last spring sets in and their armies are broken up."

A BLESBOK READY FOR COMBAT

Gordon Cumming drew a similar picture. He saw not the plains only, but the very hillsides, as far as the eye could strain, alive with the animals, so that at one time he beheld hundreds of thousands of antelopes. Yet the mighty hosts that he saw were as nothing, the Boers told him, compared with the numbers that they had been wont to view on these mad marches of former years.

We must leave the gazelles, and pass to one or two allied antelopes, of which the dibatag, with its forward-inclined horns, and the gerenuk, with a neck like that of a miniature giraffe and hook-like horns curved forward, are notable. Next we have the fine Indian blackbuck, which ranges over a wide area in India, and shows considerable variety in point of size. Major F. G. Alexander, who has had considerable experience of this animal in close upon a dozen different areas, has the interesting theory that the superiority of the largest animals arises from the abundance of salt to which they have access.

Next we have, in the chiru and the saiga, two related antelopes remarkable for a swollen proboscis. In the chiru this abnormality is less pronounced than in the saiga, in which the nose is so bloated and the snout so pig-like that one cannot resist the impression that at one stage of its career the saiga must have been developing on lines parallel to the tapir. Seen from the front the saiga suggests to the eye either that its nose has been badly stung by bees, or that it is on the way to cultivating a trunk. This animal possesses a sentimental value for Britons, for the saiga is one of the only two antelopes, the other being the extinct *Gazella anglica*, that ever found their way to our shores. At the present time the saiga is confined to the steppes of Eastern Europe and Western Asia.

ATHLETIC EMOTION—THE HARTEBEEST

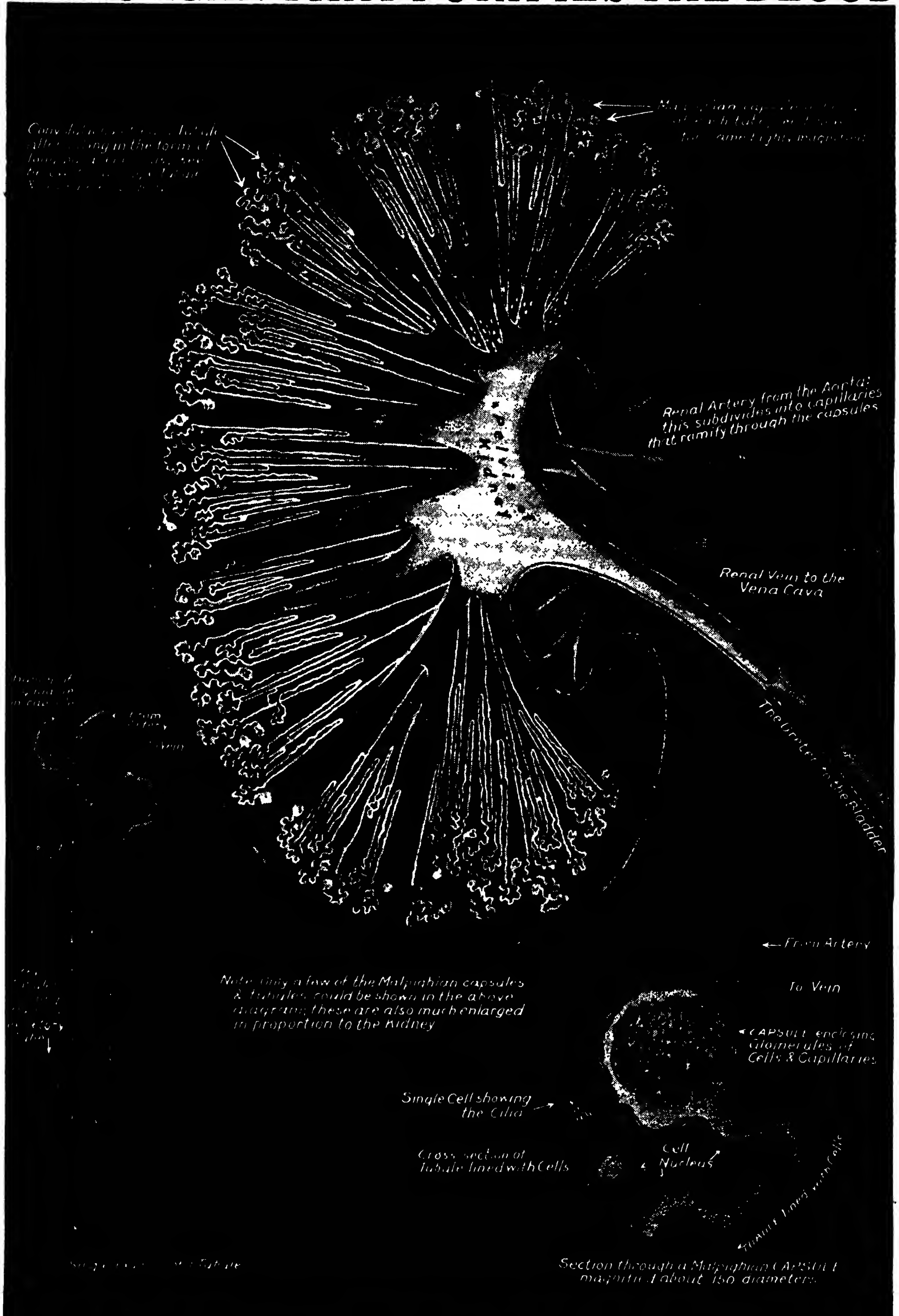
Passing the waterbuck with the note that this is one of two antelopes, the reedbuck being the other, which does not quit the low-lying marshy plains in the rainy season, we reach the delightful little klipspringer already mentioned, wherein the joy of life seems to be embodied. Not even the alert and sure-footed chamois can compare with the klipspringer in the address with which it leaps from crag to crag. Its home is in the stoniest hills, and from the Cape through Eastern Africa away up to Abyssinia it may be found at heights as great as eight to nine thousand feet above sea-level. With just a passing reference to the famous rock-leaping rhebok, to the oribis, which, thanks to their protective colouring, only the eye of the experienced hunter can detect, we leave the pigmy antelopes with the observation that among these, including adult animals not more than twelve inches high at the shoulder, are some of the most beautiful little creatures in the whole scheme of living things, gems of beauty and bone and muscle, popping in and out of the grass like hares, and speeding away when startled like birds skimming low.

Our chapter closes with the gnus, a species of which is described in some detail on page 301. All the gnus, or wildebeests, with their allies, the hartebeests and blesbok, are simply freakish antelopes related to cattle, and more especially to the African buffalo. We have first the white-tailed gnu, next the brindled gnu, or blue wildebeest, then half a dozen species of wildebeest, all powerful, fleet-footed, enduring animals, in which the passion of all antelopes, from elands to springbuck, for expressing emotion by wild and extravagant leapings and caperings, reaches its highest point. Mr. Roosevelt during his recent African trip saw one of the wildebeest leap clear over the back of an adult companion, taking a high anthill in its next stride.

But there is some sort of method in what we choose to call the madness of these bucking, leaping gnus, as the hunter discovers who makes too near an approach to one. It would afford five minutes' entertainment in a company of naturalists to take their views as to the animal most to be feared in the London Zoo. Probably they would all be wrong. The Zoo authorities deliberately declare that not the elephant, nor the rhinoceros, nor the unchangeable hunters belonging to the cat tribe, but the gnus are the most dangerous animals they possess.

MASKED GUILE—THE TREACHEROUS WHITE-TAILED GNU

THE ORGAN THAT PURIFIES THE BLOOD



These picture-diagrams show graphically Nature's marvellous methods of ridding the human organism of waste products. Each successive diagram depicts a smaller portion of the structure of this organ under higher magnification, thus leading the mind further into the labyrinth of mystery.

INTERNAL LABORATORIES

A System, Creative and Purifying, that forms Scavenging Cells, Traps Microbes, Filters Poisons, and makes Chemical Secretions

HALF-KNOWN GLANDS AND THEIR USES

We now come to the last of the systems, concerned with the animal life of the body, which are required for the maintenance of the brain. We cannot exactly speak of the glandular system as a unit, in the sense which applies to the circulatory or respiratory system. For there are glands of one sort or another in very nearly every part of the body. There are none in the brain, nor is the brain itself a gland, though we may recall the celebrated assertion of the German materialist of the nineteenth century, Karl Vogt, that the brain secretes thought as the liver secretes bile—as contemptible a piece of folly as history records. But though there are no glands in the brain, nor in bone or muscles, we have already seen that the red bone-marrow produces red blood-cells, and it really has as much title to be called glandular tissue as have the lymphatic glands which produce nothing but white blood-cells.

Further, even muscles produce certain characteristic products which enter the blood and may affect the rest of the body. Nothing can live without producing certain chemical substances. These must pass into the blood, and practically amount to the secretion of a gland. The point is not academic but practical, for it is one of the great advances of modern physiology to learn that all manner of unsuspected tissues that seem to do nothing are really producing, by their lives, certain substances which they add to the blood as it passes through them, and which, though perhaps exceedingly minute in quantity, may be absolutely essential for life.

Our ideas of a gland must therefore be elastic, but meanwhile we must start with what has long been known. A typical gland is a collection of cells, with a tube running from them, into which, on occasion, they pour a special fluid which has been made by them from the blood. The details vary, but the principle remains. The active agents are living cells, of high type, usually with large nuclei, which deliberately extract from the blood certain of its constituents, and manufacture special new products therefrom. Thus, the albumin of milk is not the albumin of blood, though it is made from the albumin of blood; and this case is typical. But we note already that the duct is not essential, for the secretion of the gland-cells may be added to the blood as it flows through the gland, and thus we learn to recognise the special group of glands or glandular tissues that are called ductless.

Let us first dismiss the "blood-forming glands," as they used to be called. These are the glands which produce the cells of the blood, and they should not be called "blood-forming," as if other glands did not contribute to the fluid part of the blood. These glands are all practically ductless. The lymphatic glands, such as are so often attacked by tuberculosis in the neck, have tiny vessels, called lymphatics, running to and from them. These vessels convey the lymph, but they act as ducts, also, for the young white cells made by the gland, for these young cells pass into the lymphatics that leave these glands, and not into the blood-capillaries. Lymphatic glands occur in the neck, in the armpits and groin, at the roots of the lungs (*i.e.*, round the bundle of vessels that pass into the lungs), and elsewhere. They are great traps for microbes, and extremely important in disease, notably in consumption, for to trace them and their connections is to understand the course of infection.

Just similar tissue is found in the tonsils, and in many curious patches found in the small intestine; also in the tongue, and in the back of the throat. The glands in the back of the throat—the region of

"adenoids"—and the tonsils communicate, through the neck, with the lungs, and are thus of enormous importance in relation to consumption.

At birth a large and important gland, called the thymus, is found in the upper part of the chest, just below the neck. It is very similar in structure to the tonsils, and its business is the making of white blood-cells. At about the end of the second year of independent life the thymus shrivels up, does no more work, and practically disappears. When we buy "sweetbreads" from the butcher we receive either the pancreas or the thymus of the calf.

The Battle for the Purity of the Blood that Goes on in the Spleen

Much more important is the large blood-forming gland called the spleen. There is no ground for the view that this gland is associated with ill-feeling, as when we say, "his remarks were not without a touch of spleen," but there was nothing absurd in the kind of theory which that language expresses. However, as it happens, the spleen produces white blood-cells. The organ lies under the left lower ribs, and has a structure very like that of lymphatic glands. It must produce enormous numbers of white cells. In certain diseases it enlarges—notably in malaria and typhoid fever—and while doctors rightly look for this enlargement as a "symptom" of the disease, and while it is much better not to have the disease and therefore not to have the symptom, yet no doubt the enlargement is protective, and means the increased production of white cells to fight the invaders, and probably also a considerable destruction of invaders in the spleen itself. We find a number of "giant cells" in the spleen, which are clearly phagocytes or "eating cells." Normally, they seem to confine themselves to the consumption of old and worn-out red blood-cells, but in certain diseases they may play a great part in keeping down the number of parasites in the blood.

The Strange Reserves of Life, as it Calls on Different Organs to take up the same Functions

We know nothing of any other functions of this large gland, and many writers are content to argue that we know its functions because we know so much. But our predecessors' mistakes regarding the liver and the pancreas and the reproductive glands should be a warning to us. Function precedes structure, and may employ structure for many purposes. A possible reply to this is that the spleen may be removed, without any ill consequences following, and therefore that it performs no other functions than those named. This is not a good argument, though the experimental physiologists employ it freely. More and more we are learning that there are various functions of the body—by no means all, of course—which are normally performed by one organ or in one way, but can be performed by other organs, or in other ways, when occasion requires. This would not be the case if structures came first, and so made functions possible; but it is the case because life and its functions come first and create the structures they require for the better fulfilment of their purposes. They are not necessarily checkmated when some particular structure fails them, nor does it follow that that structure was useless. On the whole, one had better stick to one's spleen.

From all these glands there proceed living cells. We pass now to more typical, simpler and humbler glands which produce not-living chemical secretions. They are to be found nearly everywhere, and we have already encountered many varieties.

The Various Glands and their Secretions—Protective, Lubricant, Antiseptic

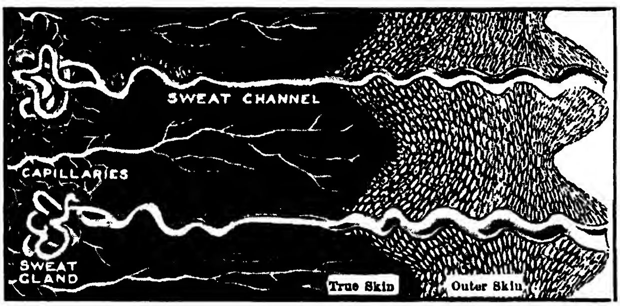
Little glands that produce mucus are found in every mucous membrane, such as lines the mouth and nose, and throat and trachea, and œsophagus and stomach, and so forth. Each of these may have special glands of its own, but it always has mucus-forming glands as well, to produce the slimy material, unpleasant to the fingers, which is so pleasant and invaluable a protective, lubricant, and antiseptic for the various linings we have named.

The skin produces no mucus, but is covered with glands that produce the secretion called sweat, or perspiration, from the blood, and each hair has glands called sebaceous, which produce *sebax*, an oily material that prevents the hair from cracking. Somewhat similar glands produce the wax of the ear. The salivary and other digestive glands of the alimentary system have already been named.

Now the microscope has taught us lately a good deal about glandular action. If we take typical gland-cells, say those which produce the pepsin of the stomach, and look at them just before a meal, we find them filled with solid particles which stain clearly with various dyes and show up well under the microscope. The gland-cells are hard at work producing these particles, and so the physiologists absurdly called

this the "resting-stage" of the gland. But when food enters the stomach, or when the gland, wherever it be, is appropriately stimulated, all these particles are melted and disappear, so that if we examine the cells after secretion we find them empty of the particles we saw before. Where the business of the gland is to produce a ferment, we find that the solid specks are made of something which is just one stage, so to say, before the ferment itself. When the necessary moment arrives, the last step is taken, the ferment itself, in liquid and usable form, appears, and is poured out of the cell. The substances just before the ferments themselves are now called pro-ferments, and chemical physiology is beginning to find in them and their behaviour the key to many of the deepest secrets of the body.

We shall have to return to some of the digestive glands, because of their surprising versatility. But first we must look briefly at the principal glands of excretion. These are the kidneys. Like all other glands, they produce a secretion, but since this is a secretion which is designed to be got rid of, we call it an excretion. The bile is similarly both a secretion and an excretion. We have no hold yet of the mere rudiments of physiology unless we well know that excretion is a fundamental necessity of life. Half the business of respiration, we already know, is excretion. The chief excrement in that case is a gas; but the body also produces solids, fortunately capable of solution in water, which equally require excretion. That is principally the business of the kidneys.



MAGNIFIED SECTION OF SKIN, SHOWING SWEAT GLANDS AND TWO PORES

They share with the lungs and the skin the duty of removing from the body the water which has partly drained through it, and has partly been made in it by the oxidation of the hydrogen atoms in the compounds of the food. Thus, about fifty ounces of fluid are removed from the blood by the kidneys every day. The quantity varies with many factors, but this is an average figure, assuming the activity of the skin to have been average also. But in these fifty ounces we find dissolved no less than two ounces of solids—*two ounces of solid matter removed from the blood every day.* This includes some five hundred grains of the remarkable compound called urea, and about ten grains of the still more celebrated compound called uric acid, crystals of which we find in gouty joints.

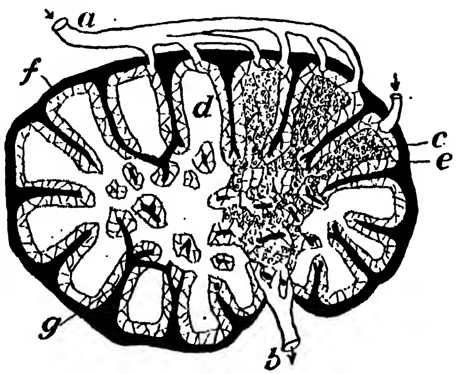
The kidneys are among the most wonderful organs in the body of man. We can trace their evolution from the remote past, when animals, such as worms, were made of a number of similar segments, strung together, and each segment had a pair of kidneys. In ourselves, each kidney is a single organ, but its structure shows that it has been developed by the union of more than a dozen separate but similar glands. Its structure is very complicated, but essentially consists of a large number of very long coiled tubes, lined with cells. Each tube begins in a little cap, supplied by a bunch of capillaries, and here the water of the blood seems to filter through, probably in an almost mechanical way. But the cells that line the long tube, through which the water drains, are most of them deep, well-nucleated, secreting cells, and it is they that extract the urea and so forth from the blood, besides producing, from certain constituents of the blood, new compounds altogether.

The action of these cells has long been regarded as mechanical, but we have every reason to suppose that it is largely vital, involving a genuine selection from the blood of certain substances, and a scrupulous retention of others. It is only when the kidney-cells are out of order that they permit the slightest trace of the precious proteins of the blood to leak away; and the discovery of the connection between this leakage and disease of the kidneys was made by the famous English physician Richard Bright, after whom Bright's disease is named. Perhaps the least common feature of this disease is pain in the loins, by the way, notwithstanding some copious public instruction to the contrary.

On the whole, however, the kidneys are

more filters than anything else. The filtration is essential to life, ridding the blood of a great many waste-products of life, and of the waste colouring-matter of bygone red-yellow cells; but it is probably less remarkable, as a chemico-vital feat, than many, less familiar, which are achieved by other glands. To these we must pass, though the physiologist is bound to observe that modern man abuses few of his organs so constantly and carelessly as his kidneys, by what he eats and drinks, and that there is no organ which suffers more frequently or disastrously from causes which are well within the control of common sense and sound physiological habits of life.

The pancreas and the liver have already been discussed as appendages of, and contributors to, the alimentary system. They are much more, and in certain cases of illness we find sugar in the secretion of the kidneys, and may naïvely suppose that this diabetes, as it is called, is due to disease of those organs. They are found to be healthy, however; and research has shown that all they do is simply to remove from the blood the excess of sugar which it contains in this disease. The blood must always contain a proportion of sugar in health, for distribution to, and combustion in, the muscles; but if that proportion becomes injuriously high, the kidneys do their best to control it. We have found that the trouble is often due to the pancreas.



SECTION OF A LYMPHATIC GLAND

The lymphatics enter the gland at *a*, pass through *e* and leave at *b*; *c*, is lymphoid tissue; *d*, cortical substance; *f*, fibrous capsule surrounding the gland, and sending divisions into *g*, the substance of the gland

This organ contains, throughout its substance, a number of little clumps of cells obviously not the same as those, the great majority, which produce the pancreatic juice, and which show the changes already described, before and after secreting it. These special cells seem to do nothing. But we now have every reason to suppose that they produce an "internal secretion" that never reaches the pancreatic duct and the bowel, but is absorbed by the blood as it passes through the pancreas, and *makes possible the combustion of sugar*. We have seen the pancreas produce several digestive ferments, invaluable in the bowel. But here is another ferment, more profoundly digestive, which makes possible the combustion of sugar in the ultimate and "secondary" digestion—the digestion of their food by the living tissues of the body. Hence we find that removal of the pancreas from the body produces rapid and fatal diabetes, and we learn, or should learn, to be very careful in supposing that the discovery of one function, or ten functions, however important, of any tissue or organ of the body, necessarily completes the tale of its powers.

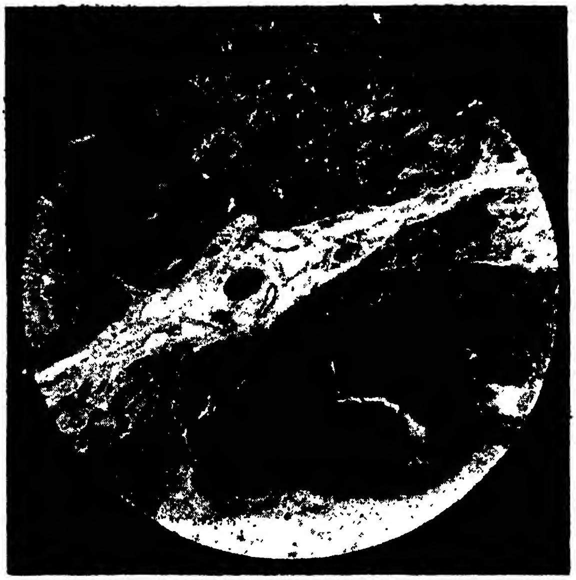
More striking still is the case of the liver. The obvious function of this large gland, far and away the largest in the body, is that it produces bile. Bile is of some use in digestion, favouring the turning of fats into an "emulsion," which is more easily attacked by the fat-splitting ferment from the pancreas. Bile is also an antiseptic, and favours the onward movements of the bowel. But it contains no digestive ferment, and must be looked upon as essentially an excrement. It is not a particularly poisonous excrement, however, and large quantities of it may pervade the body for months or years in jaundice with far less injury than might be expected.

It seems to owe its colour to the remains of old red blood-cells, which are partly broken down in the liver. It has a bitter taste, to which we allude when we talk of "gall and wormwood," and, since it is useful in digestion, it is not poured continuously into the bowel, but is stored up in what is called the gall-bladder, a small receptacle lying just under the liver. If the bile solidifies here, it produces the "gall-stones" which often require the kindly aid of the surgeon for their removal.

But this obvious biliary function of the liver, which long prevented the physiologists from looking for any more, is really only one of many. This is indeed a marvellous organ, with so many important functions that we may well assent to the double meaning of the admirable jest: "Is life worth living? It depends upon the liver." More remarkable still is the fact that these numerous, diverse, and subtle functions are performed by an organ which, however huge, contains only

one type of cell. If it had contained eight or ten notably different kinds of cell, physiologists would long have hunted about to discover a function for each type of cell, on the view that structures comes first, and then discharge functions. They could not realise the infinitely more profound idea that Life does what it needs, as it pleases, making one structure or many when it will.

The liver-cell, a simple enough thing to look at, which discharges eight or more functions, is, after all, a mere pedant compared with the amœba, which discharges all the functions of life, including sensation and movement, though it is only a single cell. We must insist upon this, which is one of the most important generalisations of modern physiology; and we may see its supreme significance when we reach the brain, and have to decide whether the structure called brain was evolved first, by chance and natural selection, and discharges a function called mind, which is destroyed when the brain is destroyed, or whether mind came first, and created the structure called brain, for its better expression. Perhaps now we see that the just physiological understanding of the relation between structure and function, in the liver and the brain as well, determines the verdict of science on the question of immortality. To this high theme we must return.



MICRO-PHOTOGRAPH OF A SECTION OF A HUMAN LYMPHATIC GLAND

Now let us see what further functions the life of the body thinks fit to perform through the medium of the liver-cells. We have named only one as yet. Secondly, the liver produces the substance called urea, from various compounds that circulate in the blood, having been derived from the breaking down of the proteins in the food. This is a very serious business, for we have just seen that about five hundred grains of urea leave the body daily by the kidneys, and a small quantity also leaves it by the skin. But the kidneys and the skin merely remove what the liver has made; and in the absence of this function the body would soon be killed by the accumulation of its own products, which only the liver can dispose of.

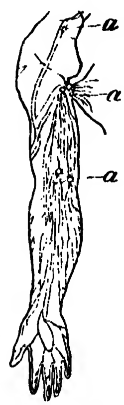
This second function of the liver involves oxidation or combustion—the production of heat, so that the blood which leaves the liver is markedly warmer than that which enters it, and thus the liver helps to maintain the temperature of the body. This is a very useful function, but as it depends upon the last we need not count it here. Merely we note that, in virtue of its bile-forming function and its urea-forming function, the liver is evidently the chemical destructor of the body. All manner of rubbish, living and dead, such as old red blood-cells, and the products of the use of the food by other tissues, are sent there to be destroyed; and in the process of destruction the clever liver contrives also to keep the body warm.

But this is no ordinary destructor, for it is capable of carefully sorting out anything really useful from what is sent to it for destruction; and, having sorted out what is useful, it acts as a storehouse, doling out to the blood thereafter just as much as may be required. We may call this a third function, though it clearly has two aspects. Red blood-cells contain a good deal of iron in their hæmoglobin, as we know. But there is only the merest trace of iron in the bile. The colouring matter of the bile is the "hæmatin" from hæmoglobin, *minus* its iron. Bile-pigment is thus practically iron-free hæmatin. The iron is carefully stored in the liver-cells when the bile is sent away, and is afterwards doled out to the blood, in quantities which the blood can hold, to go to the red bone-marrow, where new red blood-cells are being formed, and so begin the round again.

This is a rather pretty example of one of the many and subtle economies of the living body; and the physician may be disposed to remember it when he has to deal with anæmia, and contrasts the huge doses of iron that are alone effective with the very tiny daily loss of iron from the body. Plainly it is not an easy matter to get iron into the blood, and that is why the liver is so careful with it, and why even thirty grains of iron salts may be put into the bowel daily in order to get a grain or two into the blood.

There is no doubt that in some animals, and probably in some human individuals, the liver also stores fat, and serves it out in cold weather, as when an animal hibernates. Before birth, the liver is an important factory of both red and white blood-cells.

Claude Bernard, the great French physiologist, found that the liver has the most important function of storing the glucose, or sugar, which reaches it from the bowel, where it has been formed by the digestion of the starches and other sugars of the diet, and of changing it into a substance called glycogen, or "animal starch." As such it is stored in the liver; and, when and as the muscles and other parts of the body require it, the liver turns it into glucose again, and serves it out to the blood.



LYMPHATIC VESSELS IN THE ARM
a. glands.

There is some evidence to show that the liver produces an "internal secretion" which may prevent the formation of malignant growths in the body.

Lastly, we have found that the liver is the great filter of food-poisons. That, we now realise, is why the liver is placed on the route of the blood back from the bowel to the rest of the body. All the blood from the bowel has to run the gauntlet of the liver first; and large quantities of unsuitable matter, picked up by the bowel, are rejected by the liver and poured into the bile while the blood passes on to the rest of the body, and, above all, to the brain, free of these things. This notably occurs with alcohol, which is returned to the bowel by the liver in the bile, but is largely absorbed again from the bowel, reaching the liver again and again in this vicious circle. The rest of the body is saved, but the liver often pays the price of its protection, and "gin-drinker's liver" or "hobnailed liver" is the consequence. At last we understand the apparently peculiar susceptibility of this organ to this poison. Such, according to our present knowledge, are the chief functions of a liver-cell, millions of which combine to make what we call the liver.

We now come to the group of entirely "ductless glands." Doubtless the body contains many more than we yet understand at all, but here our attention must be confined to those of which we do know something—the thyroid, the supra-renals or adrenals, and the pituitary. The right behaviour, or sufficiently right behaviour, of all these glands is essential to health. They add to the blood, as it passes through them in the ordinary way, traces of some constituent or other which is essential to the right working of other parts of the body. The understanding of their functions, in some degree, has added to the powers of medicine, and many an idiot has been made intelligent by dosage with the thyroid gland of the sheep, while "adrenalin" and pituitary extract are also largely used in medicine to-day.

The thyroid gland is a double organ, with an isthmus joining its two sides, and lies on either side of the windpipe, just below the larynx. It is filled with a number of minute spaces, lined with secreting cells. Their special and characteristic product contains iodine. If the gland does not function properly in early life, the result is the form of idiocy known as cretinism, which is markedly hereditary, and flourished greatly in various parts of Switzerland until lately, when the cretins were segregated, and their reproduction interfered with, according to the principles of "negative eugenics."

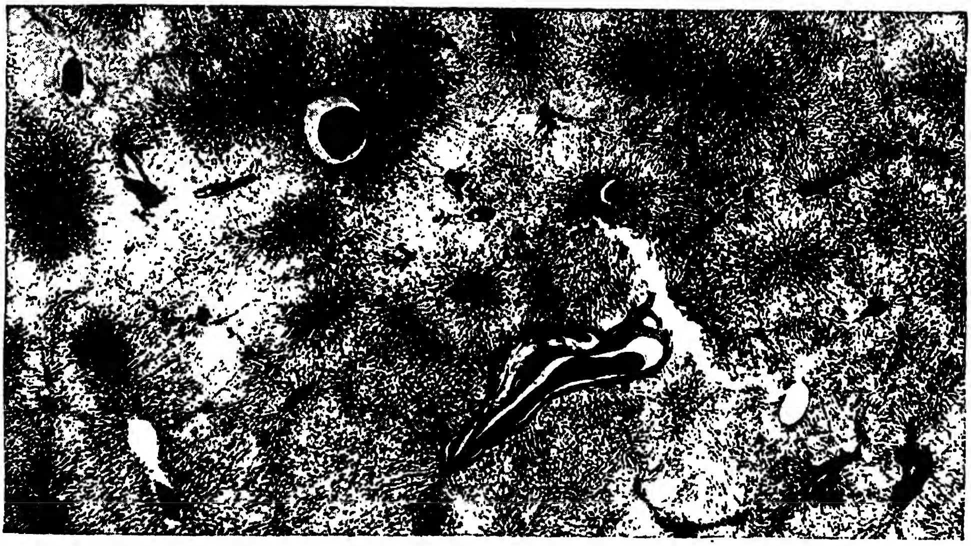
If the gland ceases to work in later life, the result is a strange malady of nutrition, affecting the skin and hair and brain and other tissues, and called myxœdema. The researches of Sir Victor Horsley, in especial upon monkeys, established the relation between the thyroid and myxœdema. To-day thyroid extract is the invaluable and almost miraculous remedy for cases of cretinism and myxœdema alike. The drug is also largely used in the treatment of obesity, which it often reduces, but its employment without medical supervision is dangerous, and has led to many accidents.

The adrenal glands are situated one above each kidney, and it has been found that, when they cease to function, usually because of invasion by tuberculosis, an extraordinary set of symptoms appears,

known as Addison's disease and especially marked by a progressive bronzing of the skin, and great weakness of the muscular tone of the arteries. We now know that the adrenals are always adding to the blood certain substances which are extraordinarily powerful in maintaining the tone of the arteries and voluntary muscles. Failing these, we must die. "Adrenalin" is now largely used by surgeons in order to contract arteries in the nose, or elsewhere, before an operation, which is thus rendered practically bloodless.

The pituitary gland is a very small organ, lying at the base of the brain, and long thought to be degenerate. But we have found that a rare and strange disease, called acromegaly, in which the bones, especially of the lower jaw and hands and feet, enlarge astonishingly, is associated with overgrowth, and perverted action, of this gland. This perverted action is often associated with cases of giantism, as the skeletons of many famous giants of the past have shown. But lately it has been found that something short of acromegaly just corresponds to the state of the skull and skeleton generally in the ancient type of man, called Neanderthal man, which was the dominant race of man in Glacial Europe, and Dr. Arthur Keith believes that the administration of pituitary extract might practically turn a modern man into a Neanderthal man.

Our survey of the glandular system is completed by reference to the racial or reproductive glands, in which what Weismann would have us call the "germ-plasm" is housed, and where, in both sexes, throughout the whole of the reproductive period, new germ-cells are being formed. In no essential does the physiology of these glands differ in man and many other creatures, and it is so important from the standpoint of life in general and of eugenics that it needs no special discussion here. One point of the highest importance, however, must be made. It has lately been learnt that the reproductive glands agree with many of those which we have already described in that, though not "ductless glands," they yet produce an internal secretion—as, for instance, the pancreas does. This internal secretion is vital for proper development in both sexes, and is responsible for the appearance of what Darwin called the "secondary sexual characters," such as the form of the body in woman, the growth of the beard and deepening of the voice in man. There is much yet to be learnt on this subject, but what we know already heightens our sense of the mutual interdependence of the parts and functions of the body, warns us against the destructive surgery which, on light pretexts, would rid the body of what it only imperfectly understands, and adds more weight than ever to the growing demand for better care of the nation's adolescent population, in whom profound internal changes, of high importance to their future, are rapidly occurring, especially and primarily in the racial glands of the body.



MICRO-PHOTOGRAPH OF A SECTION OF THE LIVER WITH THE HEPATIC VEIN INJECTED

THE CHANGING IDEAS, AS THE AGES PASS, OF WHAT IS BEAUTIFUL OR BECOMING IN DRESS

THE PAGEANT OF DRESS AS IT MAKES ITS PROCESSION THROUGH THE CENTURIES IS MUCH MORE THAN AN HISTORICAL CURIOSITY—IT REFLECTS THE IDEALS OF SUCCESSIVE GENERATIONS

THE DETAILS OF CLOTHING

What We Should Wear From Crown to Sole, and How We Should Wear it

CLOTHES THAT ASSIST OUR ENEMIES

We have discussed the principles of clothing, defining, first, the purposes for which we use it; and, second, the laws to which it must conform in meeting those purposes—as that it must be loose and absorbent. And now we must study in detail the proper clothing of the various parts of the body.

To begin with the head, there is no doubt that its natural clothing is the hair. This differs conspicuously from all other parts of the body, in that it alone retains the covering which the rest of the body has lost. This fact, however, does not deter us from clothing the head, and devoting very special attention to it, but our prime motive is not dress, but decoration. The head is conspicuous, and in all times has been used for decorative and ceremonial and honorific clothing. But, strictly, it needs none. If we are accustomed to cover it, no doubt we may catch cold if we expose it, but that is merely a question of custom. On the other hand, the midday tropical sun may fail to injure a shaven but accustomed scalp. It is thus no argument at all to say that without our headgear we catch cold. In many a northern city of these islands children go barefoot in the rain, even in winter, and do not catch cold, but they are accustomed.

The special decorative function of the headdress is too apt to conflict with the survival of the most decorative headdress, which is undoubtedly the hair. On the Darwinian theory of sexual selection, the notable preservation of the hair of the head in man and woman must be due to its decorative value, and its appreciation by members of the opposite sex. According to the analogy from the decoration of birds, the hair of men should certainly be at least as well preserved as the hair of women, but we know that, at any rate throughout the civilised world, it is not. Both sexes tend to lose the hair of the head as they grow older, and its nutrition is also apt to fail, in such a way that its pigment is not properly formed, and it turns grey; but, on the whole, men have a much greater and earlier tendency to become bald than women, and the reason must be ascertained.

No natural difference between the sexes in this respect can be discovered. The difference must be "nurtural," and only the headgear of men seems to supply it. It is true that a doctor has lately written to one of the medical journals to say that his hair has begun to grow again since he adopted a larger collar, instead of the size which, he supposes, was slightly interfering with the circulation of the blood through his neck. This would seem to implicate neckwear also; but if the doctor's inference is correct it only agrees with what has long been argued regarding the headgear of men—that it tends to interfere with the blood-supply of the scalp.

It is true that a woman usually appears to wear more upon her head than a man does. But she wears it in a very different way. She attaches her hat to her hair, so that the circulation of blood through the arteries and veins of the scalp is not interfered with. Also, there is no serious interference with the ventilation of the scalp, and its temperature is not much raised. Of course, women's hats vary in these respects, but on the whole these differences apply, and they are obviously important.

A man's usual headgear is of a very different kind. It is demonstrably superfluous. "Blue Coat" boys go without hats, and it is said that they very rarely become bald in after life. But the best proof that the scalp does not really require any protection is to be found in the skin of the face. This is mostly unprotected by hair, it is very rich in nerves and blood-vessels, and

complete exposure does it no harm. How, then, can we argue that the much thicker skin of the scalp should need protection? The truth appears to be, in many cases, at any rate, that we destroy the natural protection by our superfluous additions, and then, perhaps, they are no longer superfluous.

A famous teacher of the present writer used to declare that the great rule for health was to keep the head cool, the feet warm, and the mind easy. There is no doubt that the head should be kept cool. If, therefore, we cover it we should be sure to ventilate the covering. It is not here argued that all men should join the "hatless brigade," unless they feel inclined to, but merely that we should know what we are doing when we cover the head. Undoubtedly, for unaccustomed heads, a covering may sometimes be essential if we are to be protected from sunstroke, but this only applies to exposure to direct sunlight. The headgear does nothing to protect the head from heat. On the contrary, it raises the temperature of the head; and the very hat which may serve to protect from sunstroke may often serve to promote heatstroke in the absence of direct sunlight. It should be remembered that there is a good deal of communication between the blood-vessels of the scalp and those of the lining of the brain. Thus a hat which tends towards congestion of the scalp, in any way, also tends towards congestion of the brain.

The Need for Free Circulation of the Blood to the Extreme Top of the Head

There are two ways in which a man's headgear tends towards congestion of the scalp, and thus possibly to undesirable consequences, perhaps as regards the hair, perhaps even as regards the brain. In the first place, the flow of blood through the veins, in which the pressure of blood is always low, and the walls of which are very thin, may obviously be interfered with by the hard rim of a hat, and so we get the action which the doctor lately quoted attributes to a tight collar, compressing the superficial veins of the neck, and thus interfering with the circulation through the scalp. The arteries may be affected also, so that the scalp is somewhat starved, but the interference with the venous circulation is probably the more important. Perhaps the circulation through the scalp is always rather difficult in human beings. The scalp is tight, the head is erect, and the top of the head, where baldness so commonly begins, is probably, of all parts of the body, that which the blood finds most difficult to reach. Hence we may understand the slow atrophy of the hairs in this region which is only too common in both sexes, but especially in men.

But a man's headgear has more than the merely mechanical effect upon the circulation. It also has the effect of anything which keeps any part of the body warm. Any headgear must tend to warm the scalp by its interference with ventilation, notwithstanding the rule that one should keep one's head cool. Accurate observations can easily be made with a thermometer, to compare hats and caps in this respect. They all raise the temperature of the scalp, but the Panama hat raises it least.

The Hair a Trap for Dirt, and the Unnoticed Need for Washing the Head

We are now in a position to understand the condition of the average man's scalp, a condition which is familiar to surgeons who have to reckon with the scalp when the head is injured. They know how dirty the scalp is, and how necessary it is to clean it when they have to treat a wound of the head.

The custom of wearing the hair short probably increases the dirt of the scalp. A woman's hair catches dust and dirt, but is so abundant that the scalp itself is protected. A man has his hair cut, so that, while it remains quite long enough to act as a trap and filter for whatever is going in the air, it does not contrive to prevent what it catches from reaching the scalp. Thus the scalp of the average man, who takes the average care of his person, is the one really dirty part of his body, well calculated to catch dust, dirt, and microbes, and rich in an oily secretion, really meant for the health of the hair, which is also a very suitable culture-medium for the growth of microbes. For some unknown reason, its owner probably omits to wash this particularly exposed and necessitous part of his skin, though he neglects nothing else.

The Characteristics of the Best Kind of Headwear

Also, he frequently overheats it with his headgear, producing over-secretion of its oil, and also, as we have seen, interfering with the circulation of the blood through it. The real wonder is not that men so often lose their hair, but that so many of them retain it so well.

Be it noted that we have not here forgotten our first principles. People differ. One man does with impunity unhygienic things which another man scrupulously avoids unavailingly. All that the writer on

hygiene can ever do in this case, as in others a thousandfold more important, is to state the conditions which, for any given individual, tend on the whole in one direction or another. Many readers, whose hair and skin are of a certain fortunate type, may wear any kind of hat, and neglect their scalps to any extent and in any way, and have a fine growth of hair to the end of their days. That does not invalidate the propositions here laid down.

In general, then, our conclusions are that, if a hat is to be employed, the rim should be soft and flexible, as in a Panama, and not as in a straw boater; the weight must be as small as possible; the hat must be ventilated as far as possible; it must be worn as little as possible; and the wearer must abandon the principle that the part of the body which is most exposed to dirt and the most rapid accumulator of it is the one part which need only casually be cleansed. Some experts consider that caps are even worse than hats for the hair, because they are commonly permitted to become so excessively dirty. Of all head-coverings, the best must be the light, ventilated, wide-brimmed, soft-rimmed, regularly washed sun-hat of the cricketer, but it is not becoming.

Points in the Selection of Headwear for Purposes of Decoration

We have only to consider the silk hat to realise that this last point is the *crux* of the matter. The real business of the headgear, in either sex, is decorative, to draw attention to the face—or from it, as one sometimes suspects—and, notably, to increase the apparent height. The writer can only reiterate, in leaving this subject, his hope that, in some future day, when rational and complete education comes into vogue, there will be more faces on view which have individuality and character, and can stand on their own merits without the aid of these subterfuges.

So much for the head. As for the neck, we should remember that it conveys all the blood to and from the head. Most certainly, then, the axiom about the looseness of clothing must apply here. It is an absurdity that when anyone faints we should first have to loosen the clothing. There ought to be nothing to loosen from top to toe.

The microbes of ordinary inflammation are probably present everywhere upon the skin, in a more or less latent state. Our great protection against them is the outer skin or epidermis, which is made of horny material, and which, in its intact condition, no known microbe can pierce. This is, of course, one of the most valuable defensive functions of the epidermis, and we should beware of depriving ourselves of it. But the man who wears a frayed collar runs this risk. The collar soon scrapes off a sufficiency of the epidermis, and then microbes enter. The collar may be quite clean, and the neck also, but the microbes are there in any case, and they instantly avail themselves of the breach. Hence the liability of the back of the neck to boils or pustules. In weakly people, and notably in those whose white blood-cells are reduced in number by chronic alcoholism, these boils may be very serious, and develop into carbuncles. The moral of this is that one should never wear a frayed collar; and that, especially in any exposed part of the body, one should preserve the valuable integrity of the epidermis.

In Praise of the Clean Shirt as a Line of Defence Against Microbes

There is a good deal to be said for neckwear and for shirts that are light in colour. They need not be starched, though undoubtedly a starched surface has the advantage of not holding dirt readily; and especially is the starching of the shirt-front absurd. But lightness of colour, which means liability to soil quickly, is a virtue from the hygienic point of view. The surgeon knows perfectly well that dirt is dirt whether one sees it or not; and his chosen colours for cotton-wool or bandages or lint are always white or thereabouts. He has nothing to say to what we have already described as the great maxim of folly—that what is not seen is not dirt. Thus, while many people are always looking for materials that do not readily soil, the hygienist knows that these materials soil just as quickly as any other, and what he seeks is the material which will quickest show whatever dirt is in it. The readily soiled and frequently changed shirt is therefore an excellent garment, encouraging cleanliness, and protecting the less frequently changed underclothing beneath it.

The Manifold Virtues of the Flannel Shirt, When Properly Washed

Praise must be allotted to the light-coloured, loose-textured flannel shirt, for those who can tolerate it, but we should see to it that the flannel is thoroughly absorbent. Further, we should know that flannel clothing takes a good deal more washing than cotton or linen. The domestic tub may do admirably for handkerchiefs, but something more drastic, like the modern steam laundry, is required for the really efficient washing of flannel, especially

if it be at all heavy in texture. Various kinds of infection can survive in flannel after ordinary washing, and may propagate disease at some later date.

The looseness of the flannel shirt is a great virtue, both in itself and because it makes the shirt warmer in proportion to its weight than a close-fitting vest. Some men who cannot tolerate the sleeves of a woollen under-vest passing over the elbow may not mind the sleeves of a flannel shirt. Further, in this part of the world it is desirable for many people to protect the regions of lumbago and sciatica—the small of the back and the upper part of the back of the thigh. This will also include the kidney region, but the kidneys lie very deep indeed, and are surrounded by fat, and are far less susceptible to cold than people suppose. The muscles of the small of the back and the loins, however, are often susceptible, and pain in the back is associated not only with lumbago itself, but also with many poisonings, such as influenza, showing that these muscles, in modern man, are rather at a disadvantage, and are apt, on account of their position and the difficulty of the drainage through them, to get more than their share of poison, or fatigue products. Here is an argument for the flannel shirt, at least in susceptible men.

The Eton Jacket as a Perfect Instance of Badly Contrived Dress

The argument applies also to children, or rather to those unfortunate small boys who are, on occasion, clothed in that entirely and exceptionally absurd garment an Eton jacket. This jacket is carefully contrived to stop just when it should go on, and is commonly made of rather thin material, by no means sufficient to protect the back where the waistcoat (another remarkable garment) is devoid of cloth. As the boy is usually growing there is a constant tendency to a gap between the top of the trousers and the lower margin of coat and waistcoat. If the coat were rationally cut this would matter less. As it is, a flannel shirt may often just save the situation by bridging the gap. The perfect instance of the sacrifice of dress to decoration is furnished, however, sometimes with very serious consequences, when the small boy who has worn a flannel shirt and a sensibly long jacket all the week is put into an Eton jacket and a linen shirt on Sundays.

We must repeat that the upper part of the trunk is the chest, and that, like other chests, this has a back as well as a front. We noticed this when we were discussing the chest-protector, a peculiar structure sometimes applied to the front of the chest-wall between the two lungs. We must remember it now, when we look at the coat and waistcoat. Their business is to defend both the front and the back of the chest; and people who are susceptible to cold, and especially those who are inclined to what we absurdly call "muscular rheumatism," would do well to have the back of the waistcoat lined with flannel.

But really we should now see the absurdity of trying to keep the chest warm merely by wrapping things round it. That is all right for any other part of the body, but the chest is in an exceptional case, for we are always breathing into it air which is of a lower temperature than the blood, and may, of course, be very cold indeed.

Breathing, not Clothing, the Secret of a Healthy Chest

We *must* breathe whatever air we are in; and no wrappings round the chest affect the temperature of the air at all. There is only one natural, adequate, and never-to-be-forgotten way of protecting the lungs from cold, and that is by breathing through the nose. Even so, we could never bear the air, even of temperate zones, if it passed directly into the lungs. But it is only the air in the upper part of the air-passages that is changed at each ordinary respiration, so that the cool air from without, already partly warmed by its passage through the nose, is much further warmed before it is diffused in the lungs.

Far and away the most important requirement for the clothing of the chest depends upon the function of the organs which it encloses. The chest contains the lungs, the absolutely free and ceaseless movement of which alone meets the fundamental vital necessity, which is to breathe. This is important at all ages, and in both sexes; but perhaps the chief sufferers in this respect are growing children whose clothes are not changed often enough for their growth. No doubt many women suffer more from constriction of the chest, but there the fault is their own.

Deep Breathing and Freedom in Chest Expansion Essential for Vigour

Free and vigorous breathing has lately assumed a new importance in hygiene, and this is the place where we should acquaint ourselves with it. Thus many students suppose that the reason why the microbe of consumption so commonly attacks the apex of the lung is that this is the part of the organ which is least aerated, because

"THE PERFECT WOMAN, NOBLY PLANNED"

Physiological and artistic opinion is unanimous on the use and beauty of the twenty-five to twenty-eight inch feminine waist, but many unwise women appear to prefer what wise people know is deformity.

its movement is least vigorous and free. The writer doubts the truth of this argument, the susceptibility of the apex of the lung probably being more dependent upon the route of infection travelled by the microbes from the throat to the chest. But at any rate there is no doubt that breathing exercises, carefully graduated and designed, are of real value in the treatment of consumption. And, if this be so, we may reasonably suppose that good habits of breathing may also serve towards the prevention of the disease. Indeed, one of the reasons why open air seems to be superior to fresh air, as we have already argued, may be that the open air stimulates us to breathe it more deeply.

As we shall later see, it is a universal law of life that all living organs and functions, normally meant for regular employment, require such employment for their health. Thus the health of the lungs is dependent upon adequate exercise, too commonly denied them by civilised man in these days. At the very least, then, the clothing of the chest must be such as to permit the freest possible expansion of the lungs. In both sexes, and at all ages, notwithstanding what physiologists used to teach, the natural act of breathing is so performed as to effect especially the expansion of the lower part of the chest.

The Need for Keeping Up the Tone of the Muscles of the Body

Sir Arthur Evans has shown us that the women of the Court of Minos, in Knossos, constricted their waists with corsets at the height of the Cretan civilisation, three thousand five hundred years ago, and the practice may survive the teachings of modern physiology, but those teachings must nevertheless be expressed.

Diaphragmatic breathing involves the forward movement of the abdomen, and on that ground the clothing of the abdomen must also be loose. But there is another and special reason why we should be careful to clothe ourselves so as to leave the abdomen free.

The front wall of the abdomen is a sheet of elastic muscle. Its primary function may be to contract and move the trunk of the body. But it has the no less important function of holding the abdomen together, and of constantly exercising some pressure upon its contents. Like other muscular tissue, that of the abdominal wall should be, throughout our waking lives, in a state of slight contraction, which is called its tone. This tone of the abdominal wall, together with its elasticity, serves the act of expiration, which depends upon elastic recoil. But it also serves the health of the abdominal contents, in several ways. The abdomen is the great blood-reservoir of the body, for its veins could easily accommodate all the blood the body contains—with fatal results, of course. The firm pressure of the abdominal wall upon the abdominal contents, together with the atmospheric pressure, serves to regulate the quantity of blood in the abdominal veins. This pressure is also a stimulant to the liver, tending to avert congestion, and aiding the flow of bile. More important still, it aids the movements of the stomach and bowel.

The Dangers of Artificial Supports in the Name of Shapeliness

No elastic binder or belt ever yet contrived can rival the abdominal wall in this respect. But directly the abdominal wall becomes relaxed, losing its tone, or losing its elasticity from being overstretched, as too often happens in over-fed or in sedentary persons, the normal aid to the action of the stomach and bowel is withheld, and they lose their tone, and respond too feebly to the st mulus of their contents.

Constipation, in short, is the penalty, with all that it involves. This malady has many causes in civilised life, and cannot be disposed of here with a word; but there is no doubt that it is substantially contributed to in very nearly all women by the habit of wearing clothing which artificially supports, *and therefore paralyses*, the abdominal wall. For it is a law of life that a supported structure ceases to support itself. Put a whole man on crutches, and you paralyse his legs; apply artificial supports to the abdomen, supports which you entirely remove at night, and you largely paralyse the abdominal muscles, with the inevitable consequences. To compensate by the free consumption of aperient drugs is not to avoid all the penalties for outraging Nature.

Hints on Ease and Efficiency in our Footwear

The clothing of the feet remains, and it is no easy problem. Owing to their position, at the base of a long column of venous blood trying to return to the heart, and in nearness to the ground, they are very liable to become cold. Why this should lower the resistance of the body, in unaccustomed people, to the attacks of microbes we cannot say, but the fact remains. Pasteur similarly found that a fowl, normally immune to anthrax, became susceptible when devitalised by having its feet stood in cold

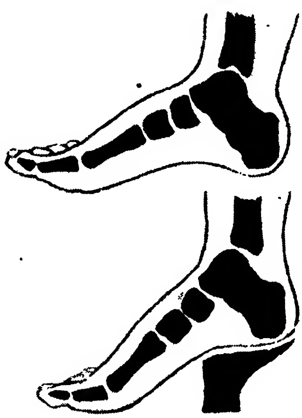
water. But we must try to ventilate the skin of the feet, while we clothe them so closely; and very nearly the most that we can do is to wear absorbent socks or stockings, and change them very frequently. If the skin of the feet is not in perfect health, a simple dusting-powder is useful.

In people who have to stand a great deal, or whose muscles are flabby, the arch of the foot tends to fall. On no account whatever should one introduce any artificial support into the boot, except by doctor's orders, and as a last resort. For if we do so we shall weaken the structures which should support the arch, and which it should be our first concern to strengthen.

Heels may be permitted for boots and shoes, as certainly protective of a part of the foot upon which the pressure is severe. But that is no reason at all why, for the sake of vanity, we should wear heels so high as to alter the entire balance of the body. The weight of the body is naturally transmitted through a line which passes through the heel. When the heel is much raised, the line of the body-weight is pushed forward, and passes through the instep, with its wonderful arch and flexible joints, as the diagram shows. This means that the arch is rendered rigid, by the transmission of the weight through it, and everything that gives elasticity and grace to the gait is destroyed. Vanity does not have matters all its own way, for it sacrifices the beauty of life in this case, just as when it interferes with the free movement of the trunk of the body. Further, the throwing forward of the pressure inside the shoe naturally prejudices the toes, and makes corns and deformities more probable. Lastly, walking now involves a certain amount of shock to the spinal cord and brain, which normal walking, with the flexible arch of the foot in action, does not entail. On this last ground, the use of rubber for the heels of boots and shoes is to be commended.

We are very hard on our toes. Thus most of us choose the length of our boots by the great toe, not caring that the second toe is, as a rule, slightly longer. The consequence is that it has to be a little bent in order to accommodate itself, and then a corn is apt to form on the top of this "hammer-toe," as the surgeon calls it. Until recently, the only effective remedy in many cases was to amputate the deformed toe, but modern surgeons usually excise the deformed joint, and so relieve the deformity. But it is better to have one's footgear long enough.

And wide enough also. The inner border of the foot is straight. At least, that is true of an infant's foot. But we soon alter all that. We cannot obtain from the bootmaker a pair of boots with straight inner edges and slanting outer edges—though that is the shape of the feet. Such boots look "pigeon-toed," and people will not wear them. We wear boots with slanting inner sides, and make our feet conform thereto. This is adding a new difficulty to those which the great toe already has to contend with, owing to man's adoption of the erect attitude. The consequence is that the deformed and over-used joint shows a peculiar susceptibility to gout, and also that what is called a bunion is very apt to form over the projection which we make by turning the toe outwards.

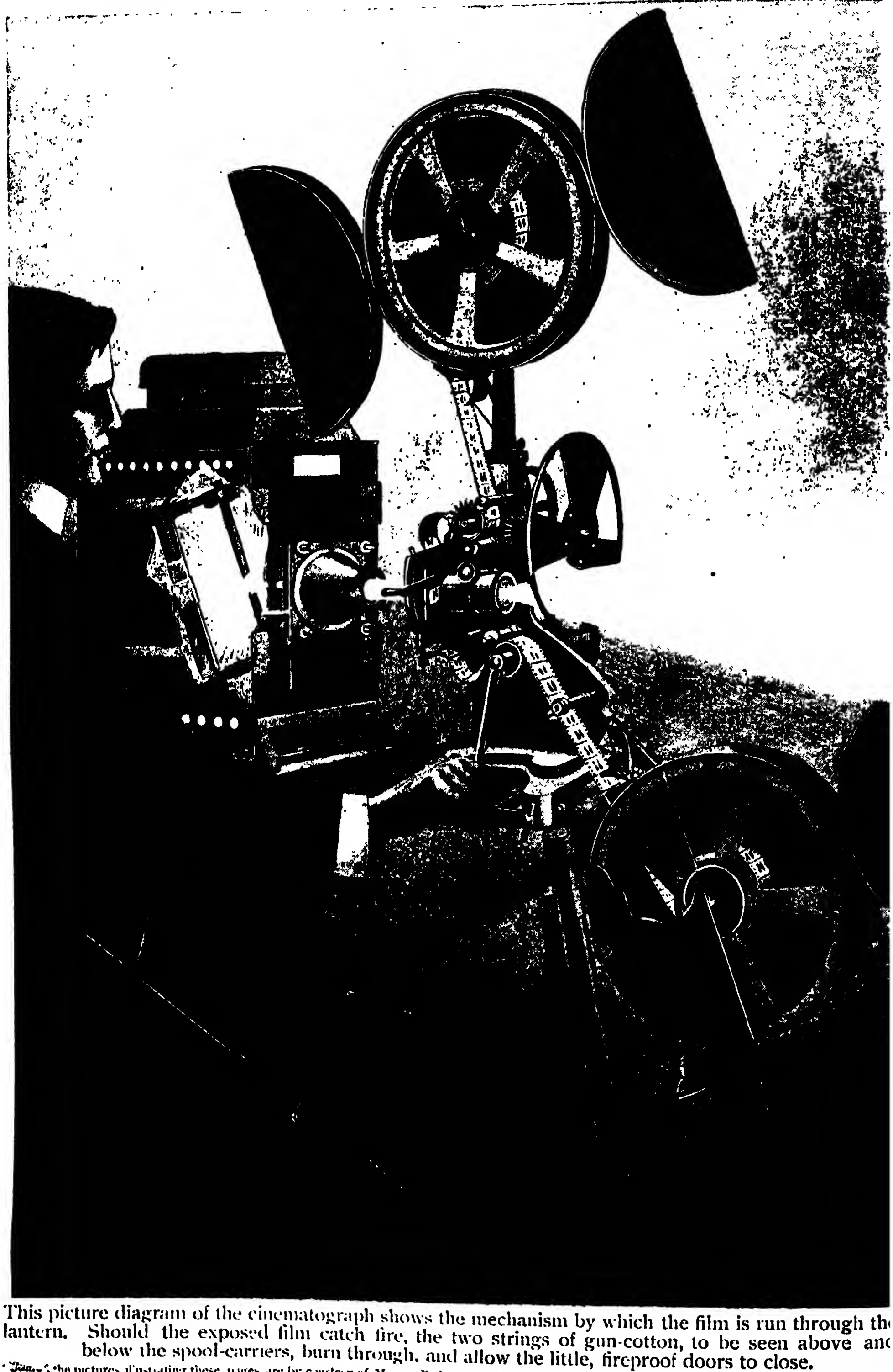


THE NATURAL POSITION OF THE FOOT, AND HOW HIGH HEELS UPSET IT

The carefully made boot will look well enough and will not produce a bunion, though no doubt it will deform the joint to some extent. It will also prevent the occurrence of what is called ingrowing toenail, which is commonly asserted to be due to cutting the toenail at the sides instead of merely straight across. The manner of cutting has nothing to do with it; only, when the nail starts "ingrowing," we naturally begin to cut it at the sides. Its ingrowing is due to irritation of the nail-forming cells at the sides of the nail, and the irritation is due to the pressure of too narrow boots. Just so does intermittent pressure upon the skin of a toe cause the form of overgrowth we call a corn.

So much, then, for the details of clothing. And now, having slept duly, bathed duly, and clothed duly, it remains to be considered how we are to comport ourselves during the day.

THE MACHINE THAT MAKES PICTURES LIVE



This picture diagram of the cinematograph shows the mechanism by which the film is run through the lantern. Should the exposed film catch fire, the two strings of gun-cotton, to be seen above and below the spool-carriers, burn through, and allow the little, fireproof doors to close.

[illegible] the pictures illustrating these pages are by courtesy of Messrs. Pathe Frères, the Charles Urban Trading Company, Mr. R. W. Paul, and Mr Oliver Pike; others are from "Moving Pictures," by Mr. F. A. Talbot.

THINGS SEEN AS THEY ARE

An Invisible World of Movement Revealed in One-Ten-Millionth of a Second by an Electric Spark

REVELATIONS OF THE CINEMATOGRAPH

At first glance it seems inexplicable that the actual movements of life can be reproduced by passing a series of pictures on a transparent material before a magic-lantern at the speed of about sixteen a second. But, as a matter of fact, every conjurer has a practical knowledge of the principle involved in the most popular of modern scientific inventions. The old saying about the quickness of the hand deceiving the eye is the explanation of the marvels of cinematography.

Men of science merely put it in other words when they say that the moving picture is an illusion produced by "persistence of vision." The human eye is extraordinarily defective, and the eye of the civilised man is blinder than that of the savage. It takes about one-twenty-fourth of a second for the ordinary human eye to get rid of a single image formed on its retina. During that one-twenty-fourth of a second, it is possible to create in succession at a single point nearly half a million electric sparks. The eye, however, cannot see even two of these sparks. All that it gets is one impression of a steady, unbroken light. That is to say, it is utterly blind to 499,999 things taking place within a few feet of it. The image of the first spark persists on the retina, and entirely stops the eye from seeing anything of the rapid succession of flashes of light.

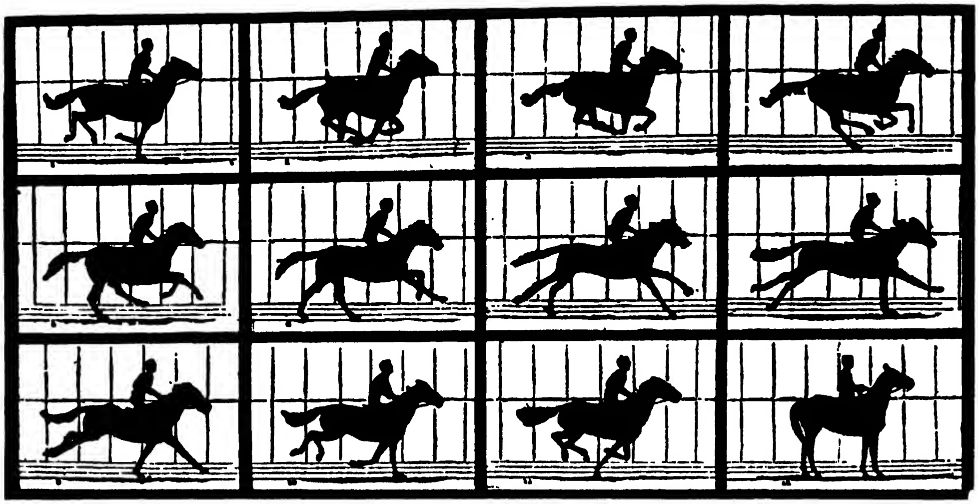
This is the defect of persistence of vision. It will easily be understood by regarding the eye as a photographic camera, which is attached by a kind of telegraph wire to the brain. When the lens of an eye is adjusted to an object, the rays of light form an image on the retina—which is a dark screen at the back of the eye. Behind the retina runs the optic nerve, and along this nerve the image is transmitted by, so to speak, a kind of telegraphic code of nervous impulses to the brain. The brain does not have a picture thrown on it. All that it receives is only a set of nervous sensations, out of which it reconstructs a conception of the actual image printed on the retina. The brain is somewhat slow in its work of reconstruction; and, having at last formed its own picture, it will retain that picture for some time after the real object has disappeared from sight. In the meantime, a multitude of other objects may flash into view, but they remain invisible. All that happens before the eyes while the brain is receiving and constructing a single picture passes unnoticed. The telegraph line is engaged.

Thus we see only a very small part of even large movements which are continually going on a few yards away from us. We cannot perceive, for instance, what motions a horse makes as he gallops past us, only a few inches from the curb on which we are standing. We cannot see the various attitudes a man makes when he is running. We cannot trace the action of our own arm when we move it very quickly. All our pictures of movement are lamentably conventional. The infinite variety of living motion is reduced by us to a single sign.

When the famous French artist Meissonier was at the height of his powers, he became the laughing-stock of France. Years of loving study of the action of horses had so trained his eye that he saw movements of their legs invisible to other men. Unfortunately, in painting some pictures of cavalry charges, he used his new knowledge; and both the public and the art critics began to lament the fact that the most wonderful of modern draughtsmen seemed suddenly to have lost his genius, and taken to drawing horses in a way that any child could see was wrong. It was generally supposed that poor Meissonier's brain was giving way. In

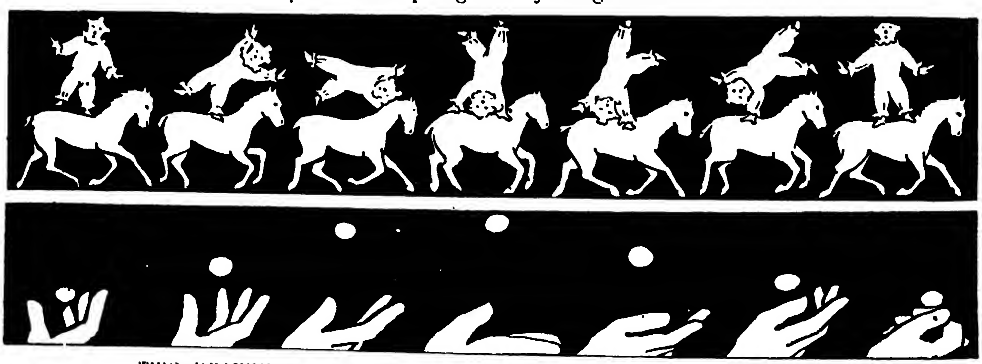
order to find anything as grotesquely bad as his drawing of the legs and attitudes of animals, it was necessary to go to the ridiculous sketches made by the lowest and most ignorant of savages—the Bushmen of South Africa.

It was in 1872 that Meissonier's reputation was apparently ruined, but in that year an Englishman named Muybridge created the new science of the study of living movements. He placed twenty-four cameras side by side along an exercising-track of horses. Across the track twenty-four threads were stretched, and each thread was connected with a powerful spring holding the shutter of a camera in position. A horse was then ridden along the track. As it passed each camera, it broke the thread controlling the shutter, thus photographing itself in its progress. Very curious were the attitudes that Mr. Muybridge succeeded in obtaining. Meissonier heard of the experiments, and invited Muybridge to give an exhibition in Paris of the wonderful pictures. The exhibition vindicated the artist. The very things for which he had been condemned became evidence of the fact that he was the quickest-eyed painter of modern times.



THE FIRST MOVING PICTURES—ELEVEN SUCCESSIVE PHOTOGRAPHS OF A GALLOPING HORSE

But a more important result of the exhibition of Muybridge's astonishing studies of movement was the impetus that it gave to the science of the moving picture, which is now one of the most popular means of amusement, and one of the most promising instruments of scientific research. Muybridge's achievement drew the attention of men throughout the civilised world to the facts of persistence of vision, and by fully revealing this defect to the human eye it led directly to the art of cinematography.

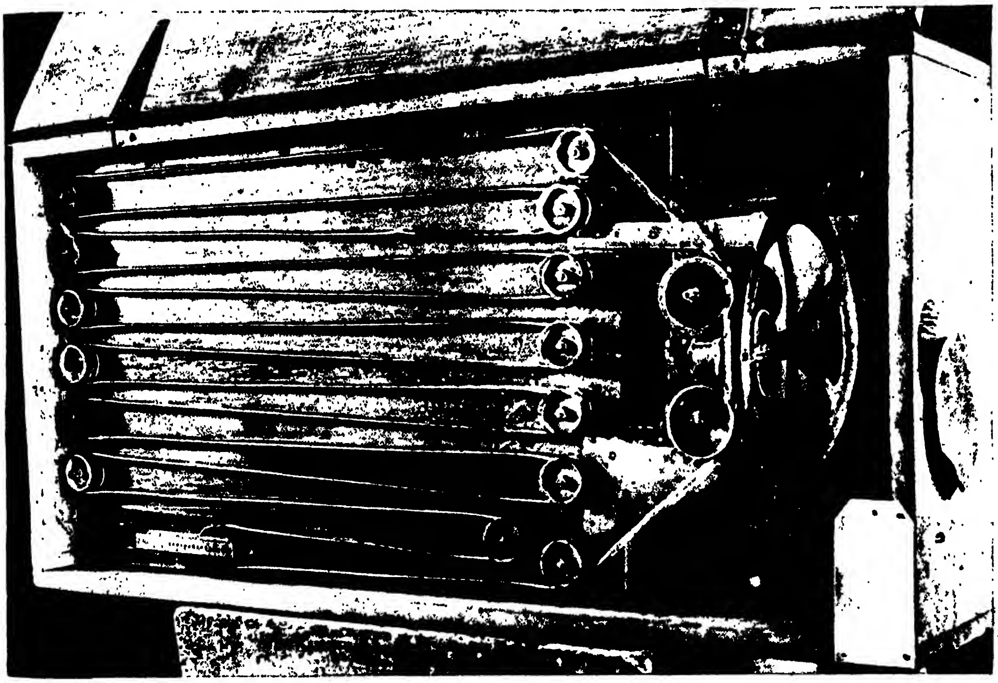


TWO DRAWINGS SHOWING THE PRINCIPLE OF THE CINEMATOGRAPH
In these drawings a single action is split into seven parts, which, passed quickly before the eye through a slot, would give the impression of a single movement.

Wonderful as is the cinematograph, it is difficult to name its inventor. The fact is

that a considerable number of men in England, France, and the United States were simultaneously engaged in working out the problem of animated photography, and success was achieved by their joint work. In the early part of the nineteenth century, Sir John Herschell and a friend made a very simple toy in which the main principle of cinematography was used. On one side of a small round piece of cardboard was painted a bird, and upon the other side was painted a birdcage. The card was suspended between two pieces of sewing silk, held between the forefinger and thumb of each hand. When the card was revolved rapidly by means of the threads, there was real pictures instead of photographs. Figures in successive stages of movement were carefully painted at regular intervals on a long band of transparent material. This band was then moved very quickly through a limelight lantern, which projected the rapid succession of images on the screen. The machine was more complicated than that now used, because Reynaud, from motives of economy, employed two lanterns and two sets of pictures.

The expense of painting the long band of pictures was very great. It was, in fact, this expense which prevented the picture-palace from becoming a cheap and popular place of entertainment thirty-five years ago.



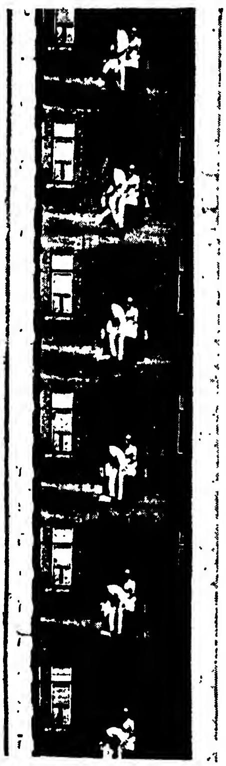
EDISON'S FIRST PEEPHOLE KINETOSCOPE, WHICH WAS COMPLETED IN 1890

produced a combined picture of a bird inside a cage. Such seems to have been the first application of the principle of persistence of vision; and when studied in connection with Muybridge's work it was further developed into the animated pictures which M. Reynaud displayed in Paris in 1877.

Reynaud's picture-palace excited great interest when it was opened. On a large white screen in the front of the stage were shown scenes of life just as striking as those now displayed in the modern way. The principal difference between Reynaud's method and the methods of modern cinematography was that the Frenchman used Reynaud only managed to make his venture practical by first throwing on the screen a motionless drawing of a room or street. This formed the setting of the animated images, in somewhat the same way as the scenery of a play serves to frame the action. Only the figures were painted on the moving transparent band, but when they were projected on the screen they combined with the set scenery. By this means was saved the cost of painting, on each of the moving pictures, the scene, as well as the figures; and Reynaud was able to delight large audiences with animated pictorial plays, in much the same manner as men

now entertain two million persons every weekday in this country, by passing photographic films before the lens of an electric lantern.

Naturally, many inventors saw that photographs could be used instead of painted pictures. Various kinds of apparatuses were devised for taking photographs at the rate of sixteen a second, and then moving them at the same speed before the eyes of the spectators. Excellent results were sometimes attained, especially by Mr. W. F. Greene, of Piccadilly, and Messrs. Marey and Demeny, of Paris. Dr. Marey had a camera which could take photographs in 1-2000th part of a second; and his fellow-worker, M. Georges Demeny, was ready with an ingenious apparatus which projected moving pictures on the screen. Only the slow and cumbersome glass plate then used in photography prevented the two Frenchmen, who are generally reckoned the fathers of cinematography, from popularising their discoveries.



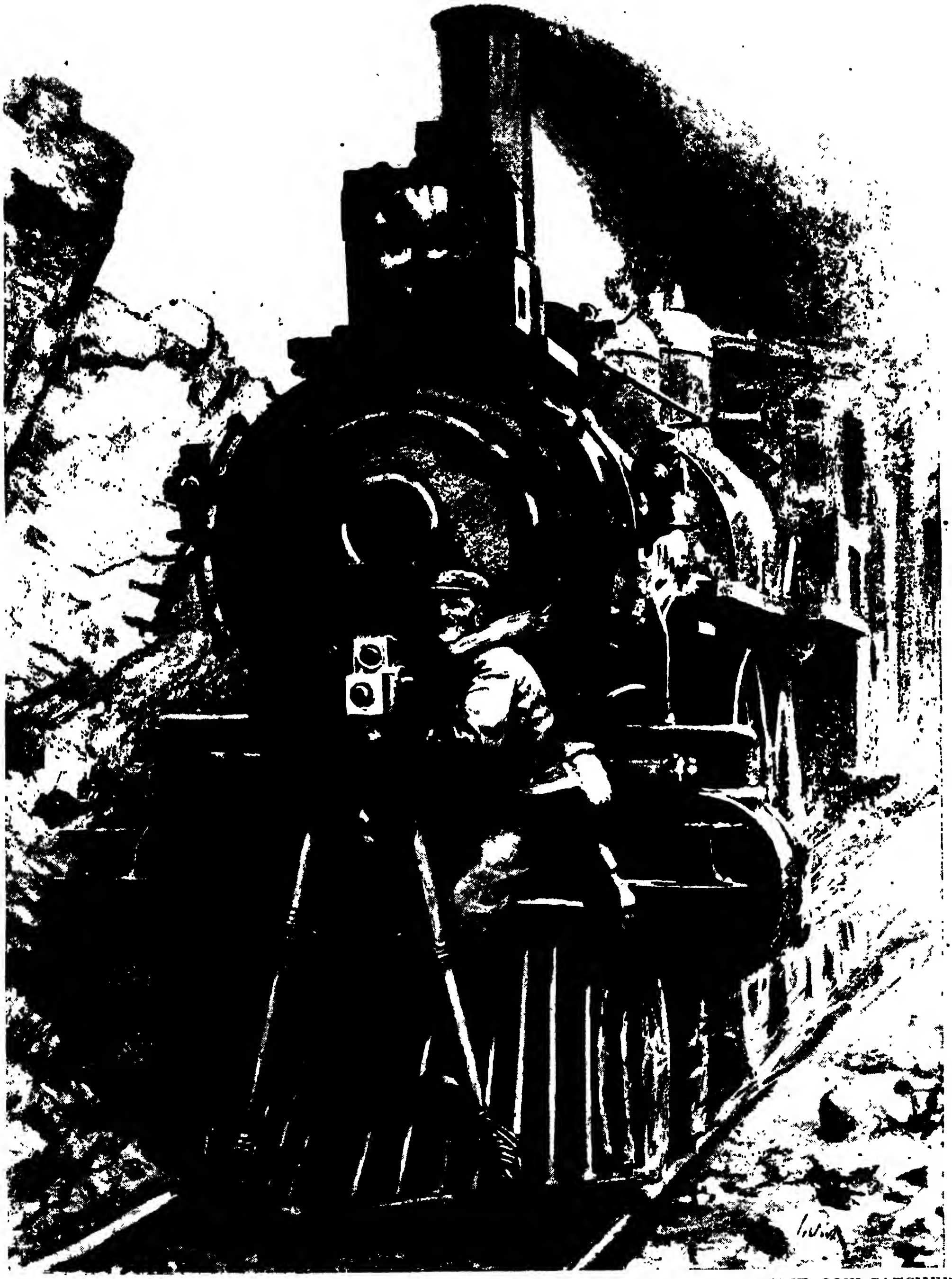
PART OF THE FIRST KINETOSCOPE FILM MADE IN ENGLAND

What was needed was a transparent photographic film, which could be made in a long band, like the transparent picture band devised by Reynaud. The position in cinematography was similar to that which obtained in literature before the invention of Gutenberg. Both books and moving pictures were practical by the slow and expensive method of hand production, but they could not become a universal force in civilisation until some means of mechanical printing was discovered. A cheap transparent photographic film was doubly necessary in cinematography. It was necessary for the marvellously rapid picture-taking required in the new science of movement, and it was needed still more for the reproduction of cinematograph images.

The search for the new film occupied for many years some of the most ingenious minds in England and America. Various materials were tested. Some were impossible, and others defective; and finally the hopes of the experimenters became centred on celluloid. This, as is generally known, is a preparation of gun-cotton and alcohol, forming a thick, honey-like liquid, which is usually rolled out in sheets and dried. The sheets, however, were not thin enough to be used in cinematography, and the firms who manufactured them refused to make anything thinner. It would not pay them, they said, to set up special machinery that would be useless as soon as the passing craze for celluloid films had passed. Had any manufacturer taken the trouble to produce the film, he would now probably be one of the richest men in the world. As it was, an American maker of photographic plates took up the study of celluloid, and produced a film, and became in a few years a multi-millionaire. In Great Britain alone there are four thousand picture-palaces, in most of which his films are often used. He controls the American market, which is much larger than the English, and his material is employed to a very considerable extent all over the world. He had the idea of inventing a camera to be used with his film, and this also brought him and his partner a vast fortune.

Mr. Eastman won the race for the celluloid film in 1889, and modern cinematography then became easily practicable. About the same time, an English experimenter, Mr. Blair, also managed to produce a celluloid film which could be used in photography and in moving pictures. But the industry was lost to our country, through the Blair Company being merged in the Eastman Company of America. It is only recently that an English firm of film-makers has struggled again to the front.

It was also an American who first applied the new material to cinematography. Mr. T. A. Edison had made a little machine for showing moving pictures, which he termed a kinetoscope. But, having found that it was useless with the glass plates then employed in photography, he had thrown it aside. In 1889, however, he heard of the discovery of Mr. Eastman; and, obtaining some of the new celluloid film, he succeeded in printing a series of photographs of movement on a continuous band. He placed the band in an improved kinetoscope, and animated photography was at last lifted from the field of scientific experiment into the realm of commercial success. Exhibited at the World's Fair at

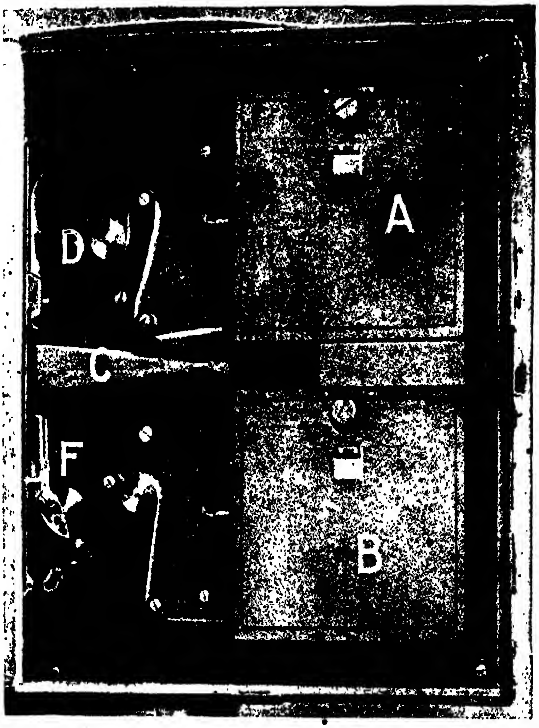


A CINEMATOGRAPHER TAKING VIEWS OF ROCKY MOUNTAIN SCENERY FROM THE COW-CATCHER OF AN EXPRESS ENGINE

Chicago in 1893, the kinetoscope amazed and delighted the public.

After dropping a nickel—a coin of the value of twopence-halfpenny—into a slot in a little wooden cabinet, the sightseer looked through a peephole, and saw a strange spectacle that lasted for half a minute. Children skipped and danced, and men and women went about the business of life, and all their living movements were vividly shown by passing a film of photographs before the eye of the spectator at the rate of forty pictures a second.

The kinetoscope was simple in construction. It consisted of nine small rollers and two large reels. Moving between the rollers and the reels was a ribbon of pictures, forty feet in length, consisting of tiny photographs printed upon a transparent strip of celluloid film. As the ribbon passed from the first large reel to the second, it came between a magnifying lens and a small electric lamp and reflector. In front of the magnifying lens was a shutter, which opened and closed swiftly and continuously, making a break between each image. Power was supplied for lighting the lamp and moving the picture-band by a small electric motor, which worked automatically when a coin was placed in the slot. At first, Edison had great trouble in keeping the film straight as it travelled over the rollers. But he managed to prevent it from slipping, by cutting out of the band of film a considerable number of small holes, into which teeth caught and kept the ribbon straight. Several little devices of this kind have been transferred from the kinetoscope to some modern moving-picture machines; and from his American patent rights in them Edison now obtains a weekly royalty of almost fabulous amount.



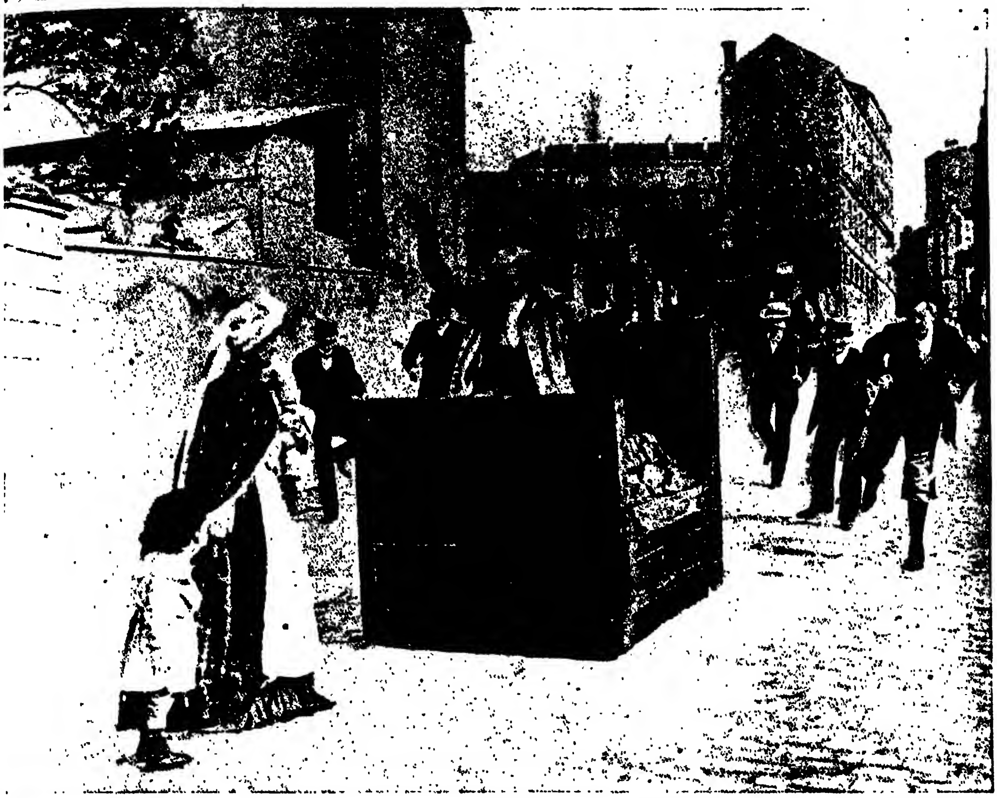
THE FILM-MOVING MECHANISM OF THE CINEMATOGRAPH CAMERA

The film is carried from the dark box A over a sprocket D, through the "gate" between the lens and the focussing tube C, where it is exposed. The film is then jerked down by the claws F to the depth of a picture, passes over another sprocket, and is wound over a bobbin in box B.

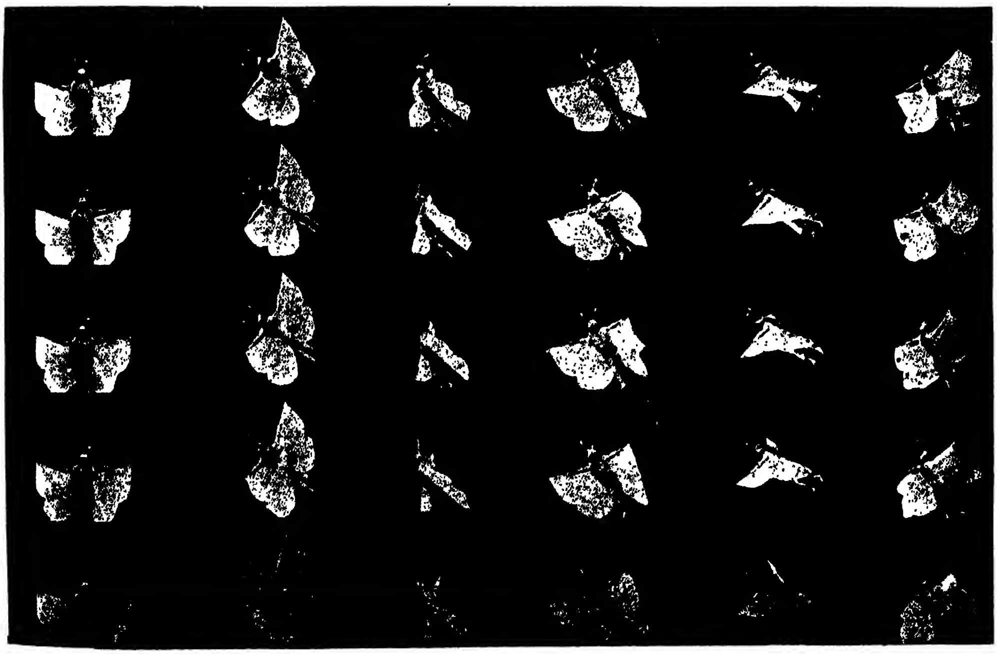
Regarding the kinetoscope merely as a new kind of toy, Edison did not trouble to patent it in Great Britain. So Mr. Robert W. Paul, a scientific instrument maker of Hatton Garden, constructed some of the machines to the order of two clients who had seen them at the World's Fair. The defect of the kinetoscope was that only one person at a time could see the picture in animation, and movements lasting more than half a minute were difficult and costly to produce. But Mr. Paul devised a special lantern through which the film was run, so that a large picture was thrown upon the screen. About three o'clock one morning in the spring of 1895, the stillness of Hatton Garden was shattered by wild and continuous shouting. The police hurried to the house, and found Mr. Paul and his fellow-workers, in their workshop, giving vent to their feelings of joy and triumph. They had just succeeded in throwing upon a screen the first perfect animated pictures. To recompense the police for their trouble, the film was run through the new lantern. It was forty feet in length, and produced a picture seven feet square. Great was the wonder of the constables, and great was their pleasure in being the first members of the public to see moving pictures thrown upon the screen.

In France, Messrs. Lumière et Fils worked on the same problem as Mr. Paul, inspired, like him, by the moving-picture toy of Edison. They sent one of their machines to London about a year after the bioscope had been worked out in Hatton Garden. The cinematograph of Messrs. Lumière was

STAGE ILLUSIONS ON THE BIOSCOPE



THE BED THAT APPEARS TO TRAVEL OF ITS OWN VOLITION



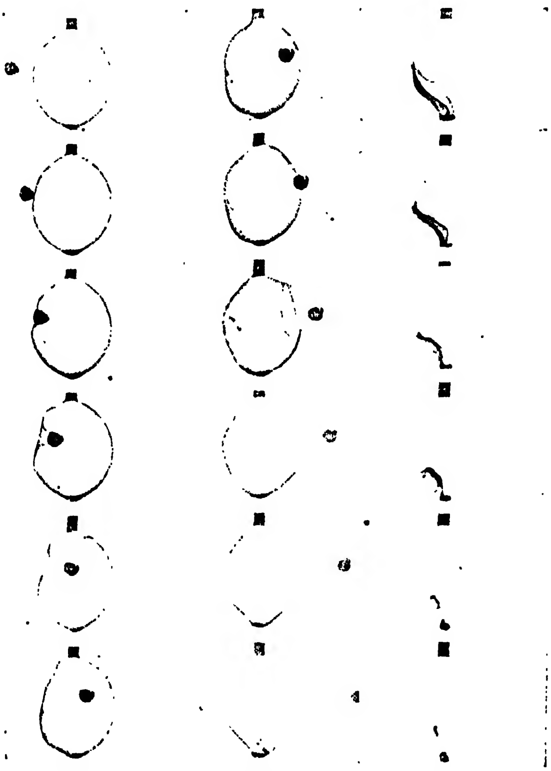
A STRIKING EXAMPLE OF TRICK PHOTOGRAPHY—THE HUMAN BUTTERFLY

The amusing trick films are obtained by devices which are in reality very simple, many effects being produced by the position of the camera in relation to the subject. The bed moving down the street, to the consternation of its owner, is being pushed by concealed stage-hands, and the human butterfly film was taken by Mr. R. W. Paul by revolving the camera itself.

the first of the two machines to arrive in the United States, where, in spite of all that Edison had done, the moving-picture toy with its peephole had not inspired any large and practical advance in popular animated photography. For some years England was the centre of the progressive movement in cinematography, but now a great part of such films as are not of a topical kind are made in France and the United States.

Some firms make a practice of issuing sets of topical films illustrating the events of the week. Messrs. Pathé led the way in 1909 with their "Animated Gazette," which is now a bi-weekly news-film with its editor and staff of operators all over the world.

It is reckoned that our four thousand picture-palaces have a daily audience of two million persons. Though this enormous multitude enters the new theatres in search merely of amusement, the moving picture is an education as well as an entertainment. Some of the films made by the lesser-known foreign firms are, unfortunately, an education in vulgarity of taste and coarseness of mind; and millions of the children of our nation now have stamped on their memories degrading scenes of life that will take long to forget. This is deplorable. Happily, there has lately been a marked improvement in the moral qualities of the average picture-play. Yet, from an educational point of view, too many of them are still made in America. Some of them depict in a brilliantly vivid fashion stirring incidents of an historical nature, but, naturally, it is not the history of the British Empire which is taught on the popular screen. There have been many complaints from Canada about the lack of good films depicting British and Imperial topics. The cinematograph is doing more than anything else to Americanise the minds of the townspeople of the great Dominion.



THE SPEED OF CINEMATOGRAPHY—A BULLET PASSING THROUGH A SOAP-BUBBLE

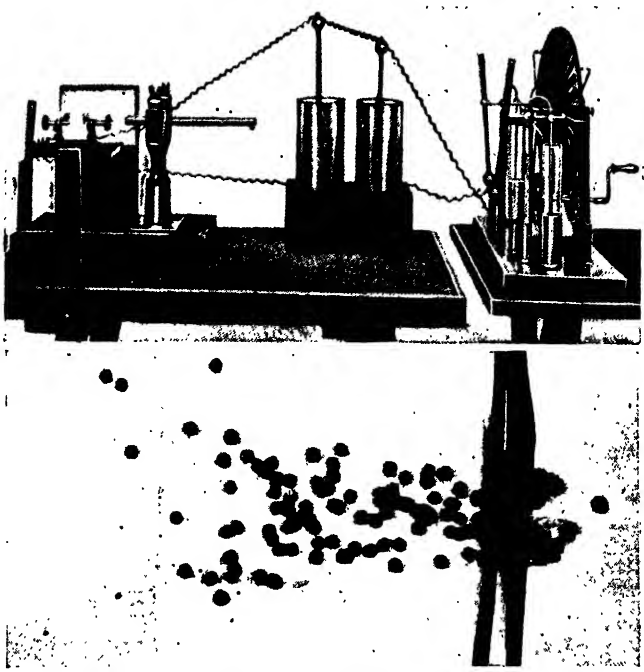
The American film is controlled by a very rich and powerful combination of firms, and it is undoubtedly an extraordinary commercial success. Edison, however, has recently resolved to make it an effective instrument in elementary education. He has devised a schoolroom machine costing about £10, in which is used a new kind of picture-band. Three photographs, each 156-1000ths of an inch in height, are printed on every breadth of film, thus taking up only one-third of the space ordinarily used. The pictures run down one side of the strip, back through the centre, and down the other side. Each set is rented to a school for about 33s. All the school lessons are dramatised; and Edison is confident that children, instead of crying to go home, will now cry for more lessons.

Nearly all the history of the United States has been worked out into pictures ready to be shown on the schoolroom screen. In the geographical lessons, the children are taken to the various countries, first shown on maps, and then the life of the people, and the scenery and industries of the nation, are brought before their eyes. Simple reading and simple arithmetic are also taught by moving pictures. The construction and working of pumps and engines and other important mechanisms are shown, first in workshops and then in machines photographed in motion, and partly made of glass so that the inside

movements are clearly revealed. A group of cinematograph operators has just been sent to Australia to take pictures of the raising and shearing of sheep. The ship will be shown carrying the wool to Liverpool, and then the factory will appear in which the material is scoured, carded, spun, dyed, woven, and made up into cloth.

We understand that some of the British educational authorities are beginning to recognise the value of the schoolroom cinematograph. For teaching natural history the instrument is very effective. It is also calculated, when combined with lectures, to make history and geography a delight instead of a task. Some of our public schools find the cinematograph very useful in the latest and most difficult branch of study. No ordinary boy or girl and very few men and women have any actual knowledge of those minute forms of life which occasion practically all the diseases to which the human body is subject. Outside the small circle of professed students of bacteriology, there is scarcely one person in ten thousand who has seen a microbe. Yet every one of us is actively engaged in fighting the agents of disease; and the individual and national struggle for health will not be organised for success until an intelligent knowledge of the conditions of this strange warfare is widespread among our people.

Already, however, it is possible to conduct a campaign of enlightenment by means of the cinematograph. Here Messrs. Pathé Frères have displayed an uncommon and praiseworthy enterprise. With their help, Dr. J. Comandon, of Paris, has managed to cinematograph through an ultra-microscope some of the most terrible microbes of disease. Their forms and motions are displayed with wonderful clearness on the screen, and their action on the blood corpuscles is also revealed. Other films show how the little animal that lives in our blood protects us from our minute but deadly foes. The animal is usually seen in the shape of a white disc, but Dr. Comandon has managed to cinematograph it in the act of shooting out a part of its jelly-like body and enclosing the microbe and devouring it. When, some years ago, Professor Metchnikoff said that this was how the microbes of disease were destroyed, and how our bodies were freed from malady, many men of science laughed at him. Now, however, we can easily see with our own eyes that Metchnikoff was right.



THE MACHINE THAT PHOTOGRAPHS FLYING BULLETS

On the right of the upper picture is an electrical machine, in the centre are two Leyden jars, and on the left is a gun combined with the photographic apparatus. Electricity is set up when the tin strips on the extreme left are struck by the first shot, a light flares up, and the flight of the succeeding shots is recorded on the plate, as shown in the lower picture, travelling from left to right, one having pierced the tin strips.

The point is very important, and it ought to be widely known, because an English man of science, Sir Almroth E. Wright, has worked it out into a new system of medicine which promises to cure without any drugs most of the infectious diseases of mankind. Many persons seem to have a childish repugnance to microbe study. They do not like to think about "the nasty things." This is silly and rather cowardly. Man must conquer the microbe, or go on suffering all sorts of complaints; and the cinematograph is an admirable instrument for spreading in schools and universities and lecture halls the new knowledge on which directly depends the health of mankind.

Cinematography is now so popular and so profitable that the development of the scientific and mechanic side of the art goes on with great rapidity. Probably the next advance in the machine will make the cinematograph so cheap and safe that it will

be brought, like the bicycle and the talking-machine, within the reach of everybody with a moderate income. Edison is already selling a machine at £10; and all that is required is an inexpensive film and a new kind of "Mudie's," at which subscribers can change their films every two or three days. When films can be printed quickly in large quantities, the moving picture will become as much a part of our home life as the six-shilling book. The novel-reader will order picture-plays from the cinematograph library; the newspaper reader will delight in the topical film; and lovers of travel and strange countries, and students of natural history and science, will entertain and instruct themselves with the pictures produced by men like Mr. F. Percy Smith and Dr. J. Comandon.

In the meantime, the picture-palace will have combined the talking-machine with the cinematograph in which objects are shown in their natural colours. Pictures that move and talk and sing were displayed on December 27, 1910, before the French Academy of Sciences by M. Léon Gaumont. The invention proved very successful, and M. Gaumont is now showing in Paris plays and operas in which speech and song and movement are reproduced by a new machine called the Chronophone. M. Gaumont began by perfecting the phonograph, so that it could register clearly and finely the voice of persons speaking at some distance from the machine. He then linked the mechanism of a cinematograph camera with that of the phonograph, and succeeded in taking, by a single operation, a moving and speaking picture of a scene from an opera.

The ordinary speaking and moving picture is difficult to obtain, and at best imperfect. The actor or singer has first to speak or sing into a phonograph. When his record is made, it is reproduced on a machine, and he listens to it, and makes appropriate movements and gestures, while the camera portrays his actions. The chronophone, however, not only reproduces by a single operation the voice and features of one performer, but large scenes from a theatre, with crowds of actors or singers; and every kind of scenery will, it is expected, soon be given over all the world in veritable living pictures.

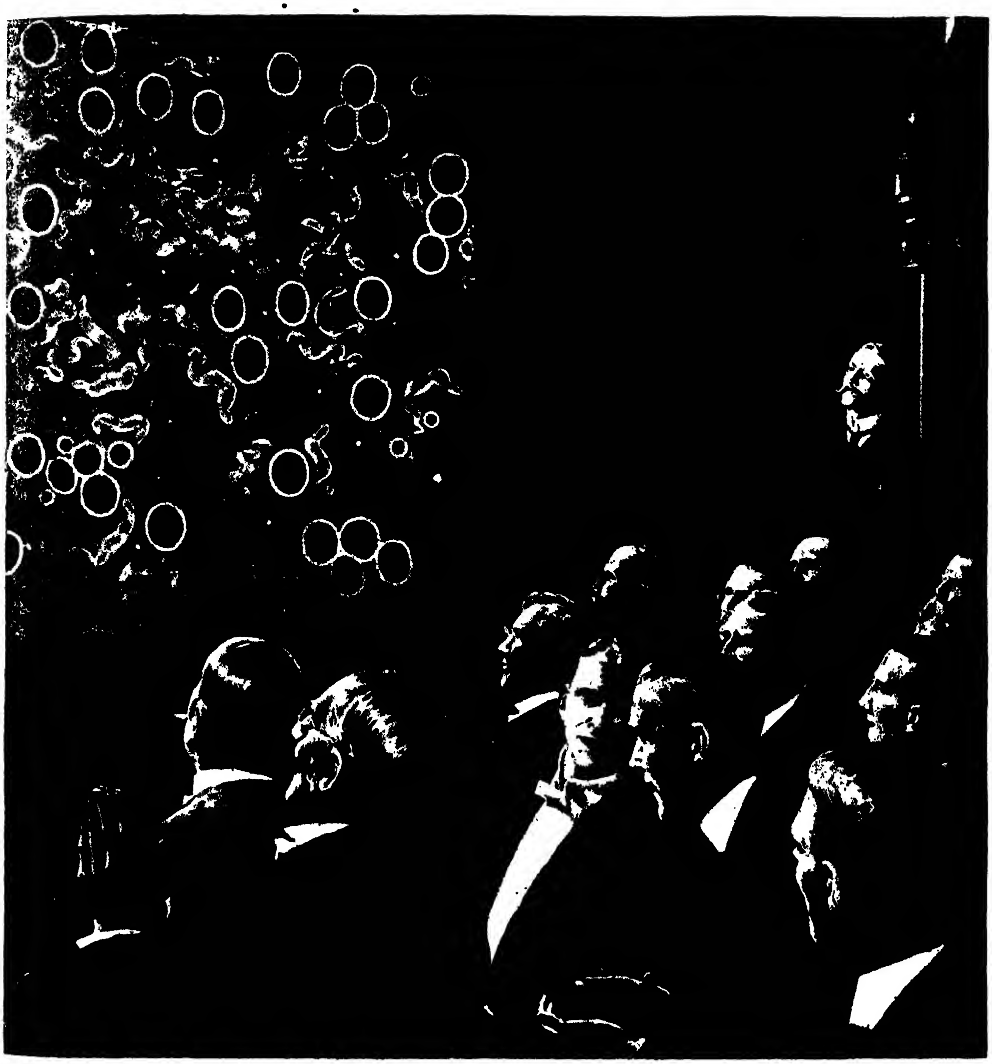
CINEMATOGRAPHY IN DARKEST AFRICA. NATIVES ATTACKING A LION, TAKEN BY MR. CHERRY KEARTON, THE FAMOUS TRAVEL-PHOTOGRAPHER

Important as is the cinematograph as a means of entertainment, it is still more valuable as an instrument of scientific research. It will be remembered that it was originally invented by Messrs. Marey and Demeny as an apparatus for the study of the science of movement, and it is in this science that its most wonderful powers are constantly being developed. A man of science need not take into consideration

the factor of cheapness; and as he often possesses a remarkable inventive talent, he can, by continual experiment, achieve results undreamt of in commercial cinematography.

For instance, Dr. C. Cranz, a professor at the Berlin Military Academy, recently took up the study of the flight of projectiles. The matter was of great practical concern to the German Empire; and Dr. Cranz, being one of the leaders of military science in the most powerful of the armed nations of the world, was able to put in ingenious use all the latest and most costly of modern means of research. The result was he succeeded in obtaining moving pictures of a bullet striking a steel plate, which promise to revolutionise the science of ballistics. Ballistics is a comprehensive term for the study of bullets, shells, and other projectiles in actual flight.

Dr. Cranz invented a new kind of cinematograph camera, in which the film moved before the lens at the marvellous speed of one hundred and fifty miles an hour. The film was run over two steel cylinders, and somewhat more than two hundred and eighty feet of it passed before the lens in the space of one second. Light was obtained by a series of electric sparks, some of which only lasted one-ten-millionth part of a second—an infinitesimal fraction of time quite beyond human comprehension. Yet the

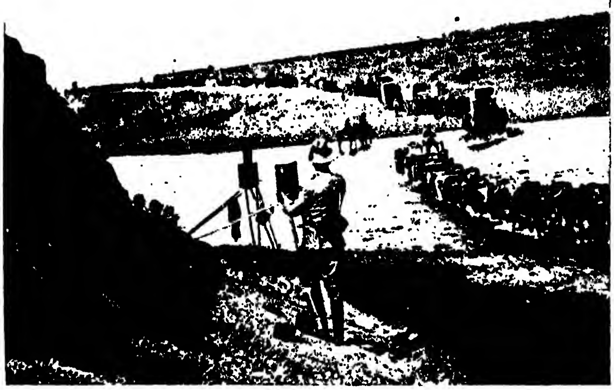


HOW SCIENCE STUDIES THE INVISIBLE—THE LIVING BACILLUS OF SLEEPING SICKNESS SHOWN ON A SCREEN

pictures obtained at this tremendous speed, and with this miraculously brief exposure, are clear and well defined, and of the standard size. As a rule, Dr. Cranz takes about five hundred consecutive pictures in one-tenth of a second, and then he throws them on the cinematograph screen at the slow speed of sixteen pictures a second.

This is about two thousand times slower than the thing actually occurred. To put it in another way, the cinematograph enables us to magnify time in the same way that the microscope enables us to magnify space. A new world of invisibility has suddenly become visible to mortal eyes. We can study the action of flight in the swiftest bullet more easily than with the unaided eye we can observe the motions of a tortoise. Very soon, in all probability, the strange and hidden structure of matter will be made plain to the eyes of a child by means of moving pictures.

As is generally known, matter consists of centres of electrical force, which form themselves into systems. These systems are the atoms of the older school of physical science. It is by the arrangement of atoms in molecules that the various elements are formed. Even the molecules are so minute that a cricket-ball would have to be magnified to the size of the earth before we could distinguish the molecules composing it. By, however, combining a cinematograph like Dr. Cranz's with the ultra-microscope, it will be possible to study the molecular movement of matter.


THE CINEMATOGRAPH IN SOUTH AFRICA

Particles of gold dust not much larger than an atom of hydrogen are placed in water. Instead of settling at the bottom of the glass, the gold particles move about in a startlingly life-like manner. It is supposed that their movements are caused by collisions with the molecules of the elements of the water. It would be easy to illuminate the strange spectacle with electric sparks, and take a series of moving pictures at a very high rate of speed. If a great number of pictures were taken, and then thrown slowly on a screen and carefully studied, we should soon know more about matter in a state of molecular collision than we do now. A world of movement that entirely escapes the eye, even when the ultra-microscope is used, could be magnified two thousand times and made apparent to everybody.

We have already referred to the fight against the invisible armies of disease that Dr J. Comandon is carrying on with his cinematograph. He began by placing the blood of a diseased animal beneath an ultra-microscope, in which the red speck was illuminated by a strong, intense ray of electric light. He then took a series of cinematograph pictures; and when these pictures were developed and printed, and thrown on a screen, an awful spectacle of life in death and death in life was revealed. A wriggling mass of snake-like forms, magnified at times to the length of half a foot, could be seen attacking the round red blood corpuscles, and destroying the little white animals that live in the blood and protect the body from the minute agents of infection. All the movement and the life history of certain microbes of disease could thus be easily studied; and a new weapon of defence was placed in the hands of the noble men of science, on the success of whose researches depends the physical welfare of the human race.

There are not many microbes that can clearly be seen through an ordinary microscope. The greater number of these secret forms of life have so transparent a structure that it is difficult to distinguish them from their surroundings. Usually they have to be killed and stained before they can be scientifically examined. A notable advance in our power over these hidden enemies was obtained by the ultra-microscope; and now, by using this instrument in combination with the cinematograph, many microbes can be caught and pictured alive. and the

processes of their existence can be slowly and carefully and continually watched.

Even the astronomer has now found the moving picture of great service in hi[redacted] science. Professor Störmer, of the C[redacted] tiania University, is busy adapting [redacted] instrument of research to the stu[redacted] the strangest and most beauti[redacted] phenomena—the Aurora [redacted] ern Lights. The A[redacted] scene of a spectac[redacted] rious loveliness[redacted] bow flame [redacted] up the [redacted] spect[redacted] es [redacted]

about this wonder of the Polar skies, but the body of facts relating to it is small. Professor Störmer has resolved to take cinematograph records of the Northern Lights at different periods of the year, and measure their relative brightness, and study on the screen all the varying details of the phenomenon. Then it will be possible to compare all the facts, and relate them to the magnetic storms and other vast and mysterious natural occurrences. It is expected that the results will be of the very highest scientific value.

This cinematograph study of the Northern Lights, however, brings out in a striking way [redacted] ins[redacted] of [redacted] ment [redacted] far from [redacted] ts in all their [redacted] s and interesting [redacted] s and topical scenes [redacted] produced by the modern [redacted] y lack the one thing that [redacted] cceeded in achieving with his [redacted] ome apparatus in 1877. They [redacted] duce the movements of life, but they [redacted] l to catch the full glory of its colours. Of course, it is possible to adopt Reynaud's method of hand-painting the images, but

A WONDERFUL SETTING—A BATTLE-SCENE FROM "THE SIEGE OF CALAIS," IN MEN AND HORSES TOOK PART

this is still very costly and labo[redacted] over, it takes away from mod[redacted] pictures that quality of actu[redacted] makes them popularly interesting and valuable from a scientific point of view.

Living in an age of science, we like to obtain in our picture-palaces a sense of wonderful achievement as well as a sense of amusement and a topical interest. It is the science of the cinematograph which first amazed the public—the science of living movement revealed in the picture of "A Shoeblack at Work in a London Street," which Mr. Robert W. Paul showed at his first public demonstration in February,

1896. The picture that created popular cinematography, and made it a large and permanent force in civilisation, was Mr. Paul's moving pictures of the Derby of 1896, showing the victory of King Edward's horse. The topical picture still remains the most attractive feature of our picture-palaces, in spite of the fact that the film-play has been developed into an astonishingly successful form of art.

Pictures in natural colours will surely form the next really important advance in cinematography. The race for the new kind of film, which will enable this advance to be made, is more strenuous than that which occurred in the matter of the celluloid film; and many of the most inventive minds of all the progressive nations are busily working towards the desired end.

The Illusion by which we can see Cinematograph Pictures in Colour

At present coloured effects in cinematography are usually obtained by an interesting illusion. There are two rival processes now before the public—the Biocolor, worked out by Mr. W. F. Greene; and the Kinemacolor, invented by Mr. Albert Smith. Mr. Greene was the first in the field with an invention in which the three primary colours—red, green, and violet—were used. Three photographs were taken one through a red screen, one through a green, and one through a violet. When developed and printed, these photographs were rapidly moved before the cinematograph lantern, the light from which passed in turn through the three screens. The picture taken through the green glass was projected through a green screen; that photographed through a red glass was projected through a red screen; and a violet screen was used with the picture taken through a violet glass.

The Wonderful Results that the Blending of Two Colours Can Give

It was found, however, that when colour was used in this way the ordinary rate of persistence of vision did not obtain. Instead of the moving pictures blending into a single coloured image, they merely produced successive flashes of green, red, and violet light. In order to obtain a natural colour effect, the speed with which the pictures were moved before the ray from the lantern had to be increased at least three times. That is to say, forty-eight pictures a second had to be thrown upon the screen, but the strain of this speed was so great that the film often broke, and stopped the spectacle. The tricolour cinematography was also very expensive. As the pace at which the pictures had to be moved was three times that of ordinary black-and-white work, three feet of film were required to record the movements of an object during the space of one second, instead of the one foot of film which was necessary in ordinary cinematography. Having realised the disadvantages of the three-screen process, Mr. W. F. Greene, in 1905, went back to an older idea of his for using only two screens. Eighteen months afterwards Mr. Albert Smith invented a somewhat similar means of obtaining an illusion of natural colours, and in 1908 his Kinemacolor was sufficiently perfected to be introduced to the public.

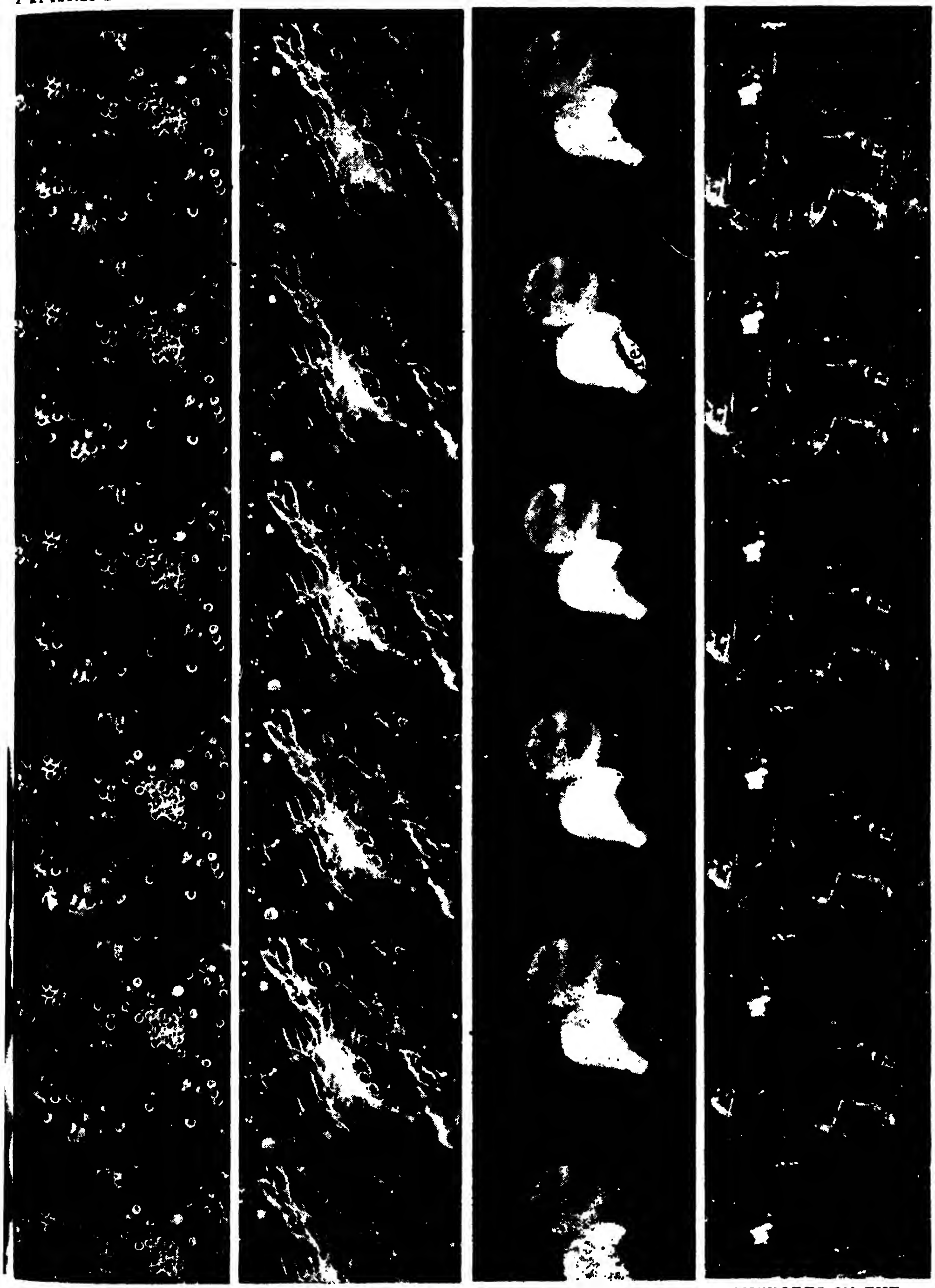
In both methods only red and green screens are employed. One picture is photographed through the red screen, and the other through the green screen; and this alternation of two of the primary colours is continued throughout the film. There is no blue or violet actually in the pictures, and no true yellow. A blue tone, however, is partially introduced by two side-ways. In the first place, there is a certain proportion of blue in the green screen, and, secondly, the use of an electric arc light in the lantern gives a blue tone to the ray.

The Recent Discovery of a Method of Printing a Colour Negative in Colours

So, in a rather small degree, the combination of these two factors compensates for the absence of the violet screen. Yet the absence of pure yellows and true blues and deep purples is marked in both of the two screen processes.

What is wanted is a new kind of film—a film on which pictures can be printed by sunlight in all their natural colours. It looks as though an English resident in Paris, Dr. J. H. Smith, is in a way to make the last and most wonderful advance in the science of cinematography. For he has discovered a means of printing on paper, from a negative, photographs of objects in their natural colours. We have seen his invention of "uto-colour" paper applied to ordinary pictures with beautiful and astonishing results; and if Dr. Smith manages completely to adapt his new process to cinematography, moving pictures in all their natural colours will be as easy to obtain and as cheap to work as black-and-white images. The cinematograph will then be doubly useful as an instrument of scientific research; and when it is used with a talking-machine it will be the most popular and marvellous form of entertainment the ingenuity of man has produced.

ANIMATED PHOTOGRAPHS OF LIFE AND MOVEMENT IN THE BODY



MICROBES OF RELAPSING FEVER

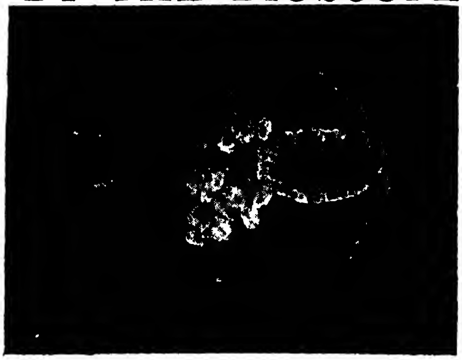
AGGLUTINATION OF MICROBES IN BLOOD

MOVEMENT OF WHITE BLOOD CELLS

MICROBES IN THE ALIMENTARY CANAL

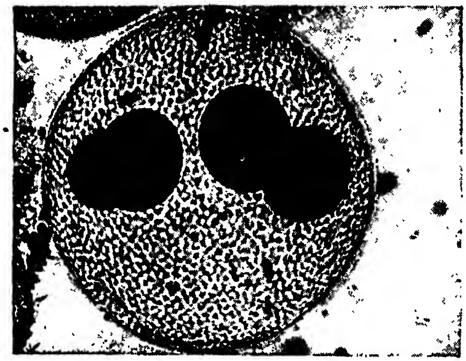
NATURE REVEALED BY THE BIOSCOPE

COPEPODA, WATER CRUSTACEANS, SWIMMING

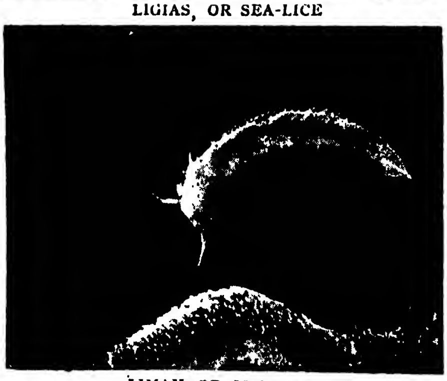


A COPEPOD CARRYING EGGS

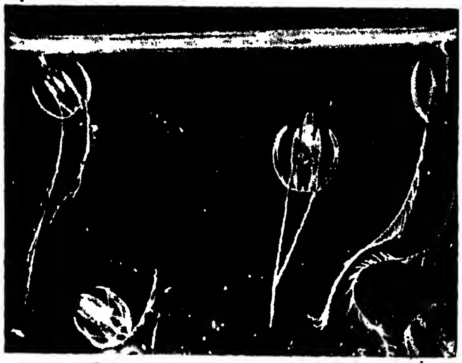
LIGIAS, OR SEA-LICE



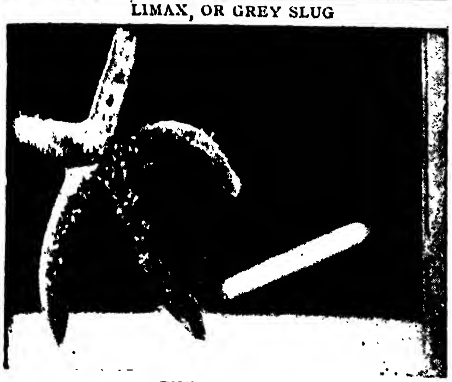
VOLVOX AND YOUNG



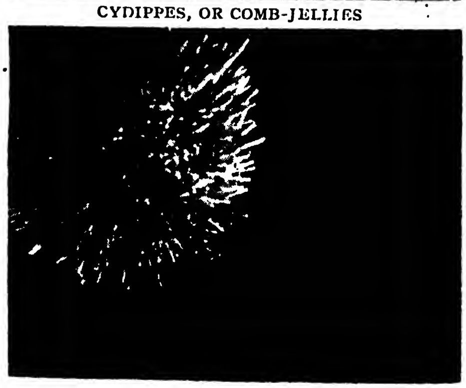
LIMAX, OR GREY SLUG



CYDIPPES, OR COMB-JELLIES



THE STAR-FISH



THE SEA-URCHIN

LIFE CAUGHT AT WORK IN MANY MOODS

A SCARAB BEETLE FORMING A PELLET

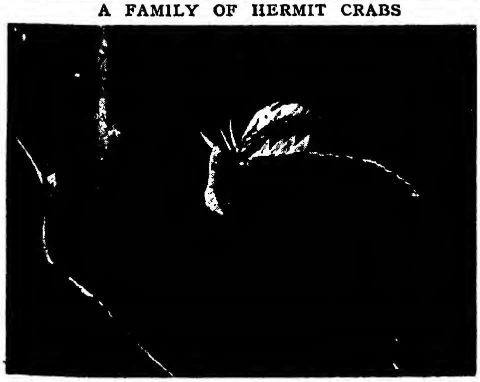
A SCARAB BEETLE PUSHING A PELLET

A TADPOLE JUST EMERGED FROM THE EGG

FIVE METAMORPHOSES OF THE FROG

A FAMILY OF HERMIT CRABS

A HERMIT CRAB OUT OF ITS SHELL



SENSITIVE PLANT WITH LEAVES CLOSED

SENSITIVE PLANT AFFECTED BY ELECTRICITY

READING SECRETS OF SEA, SOIL, AND AIR

MEDUSA, OR JELLY-FISH, SWIMMING

THE POUCHES OF A JELLY-FISH

HAWTHORN BLOSSOMS

CHESTNUT BUDS OPENING

MUSHROOMS GROWING

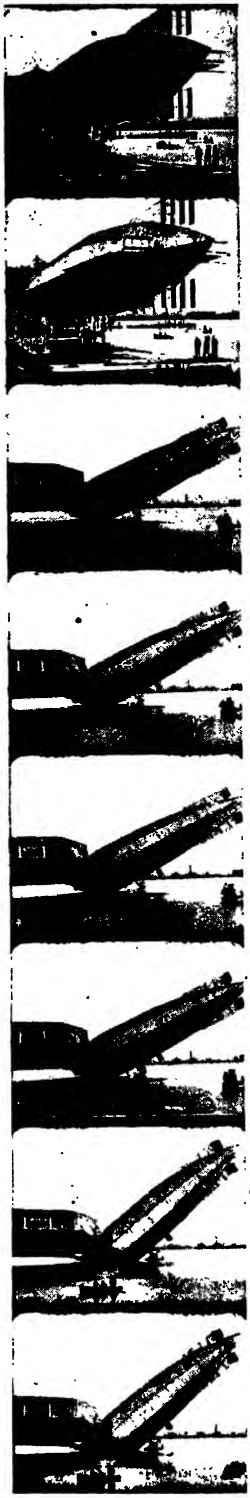
A BEAN GERMINATING

TWO PICTURES OF A SEDGE-WARBLER FEEDING ITS CUCKOO FOSTER-CHILD

FIRST AND LATEST MOVING NEWS PICTURES

THE FIRST TOPICAL FILM, THE 1896 DERBY

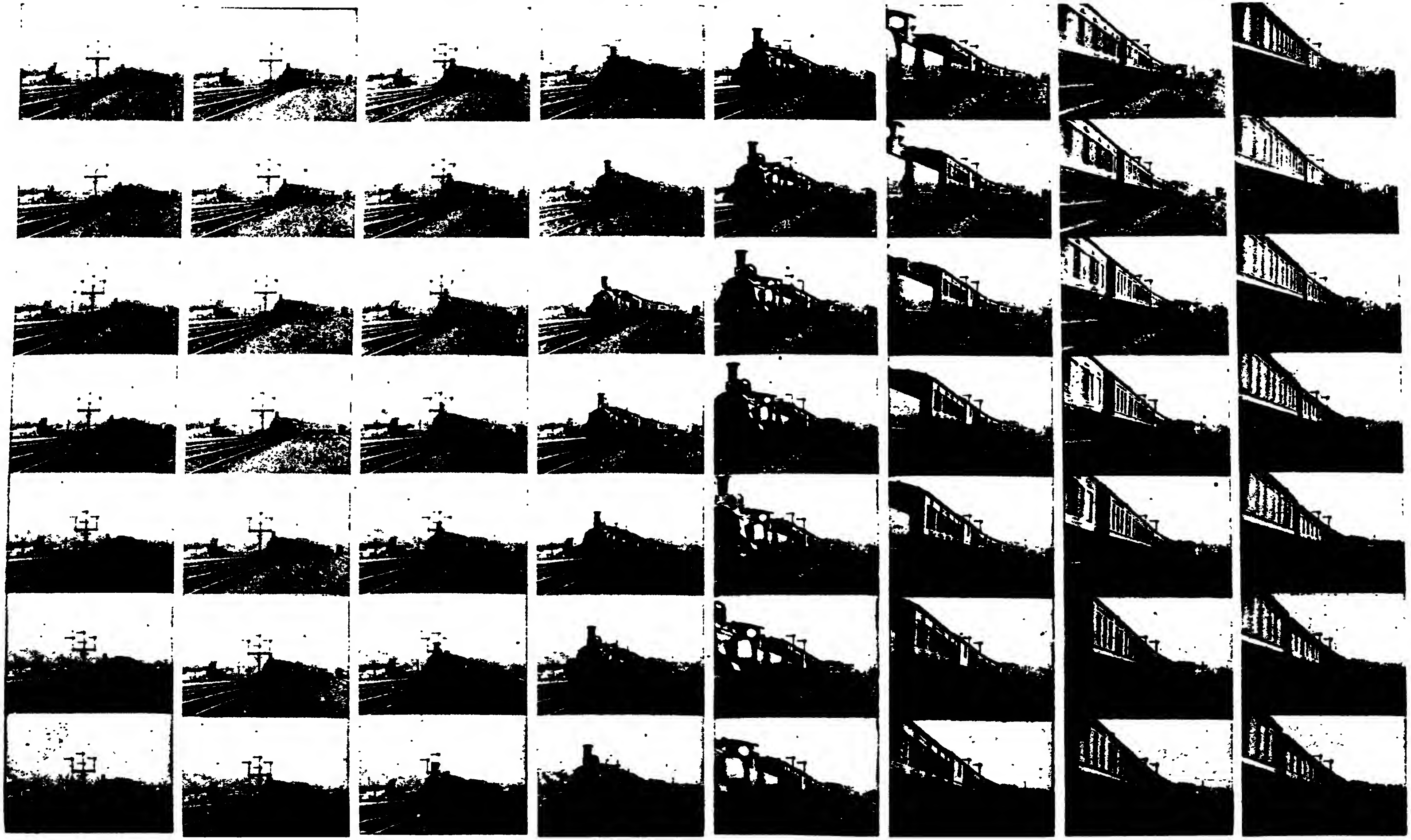
ARMY CHARGERS AT FULL GALLOP

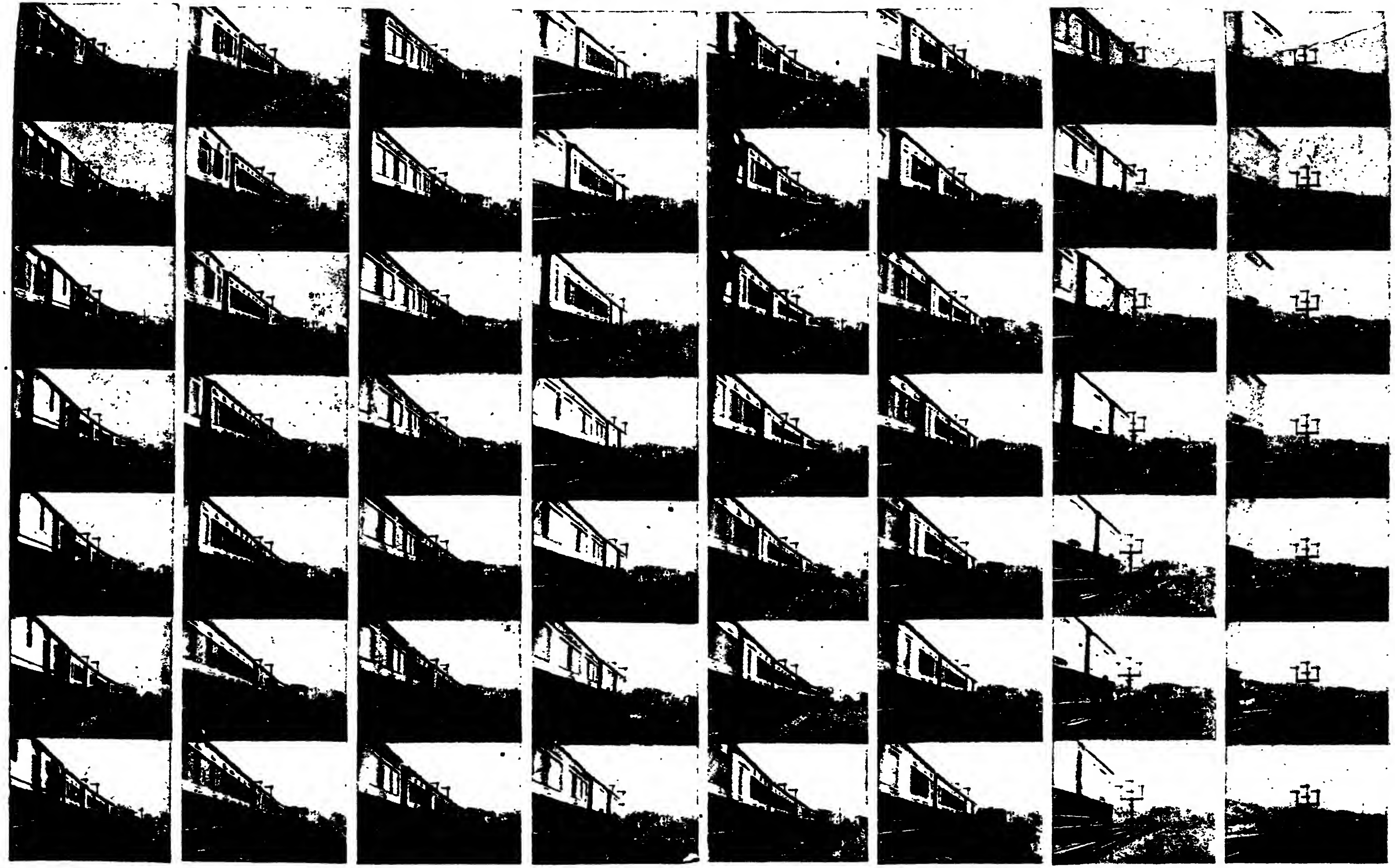


THE BURSTING OF THE MAYFLY DIRIGIBLE

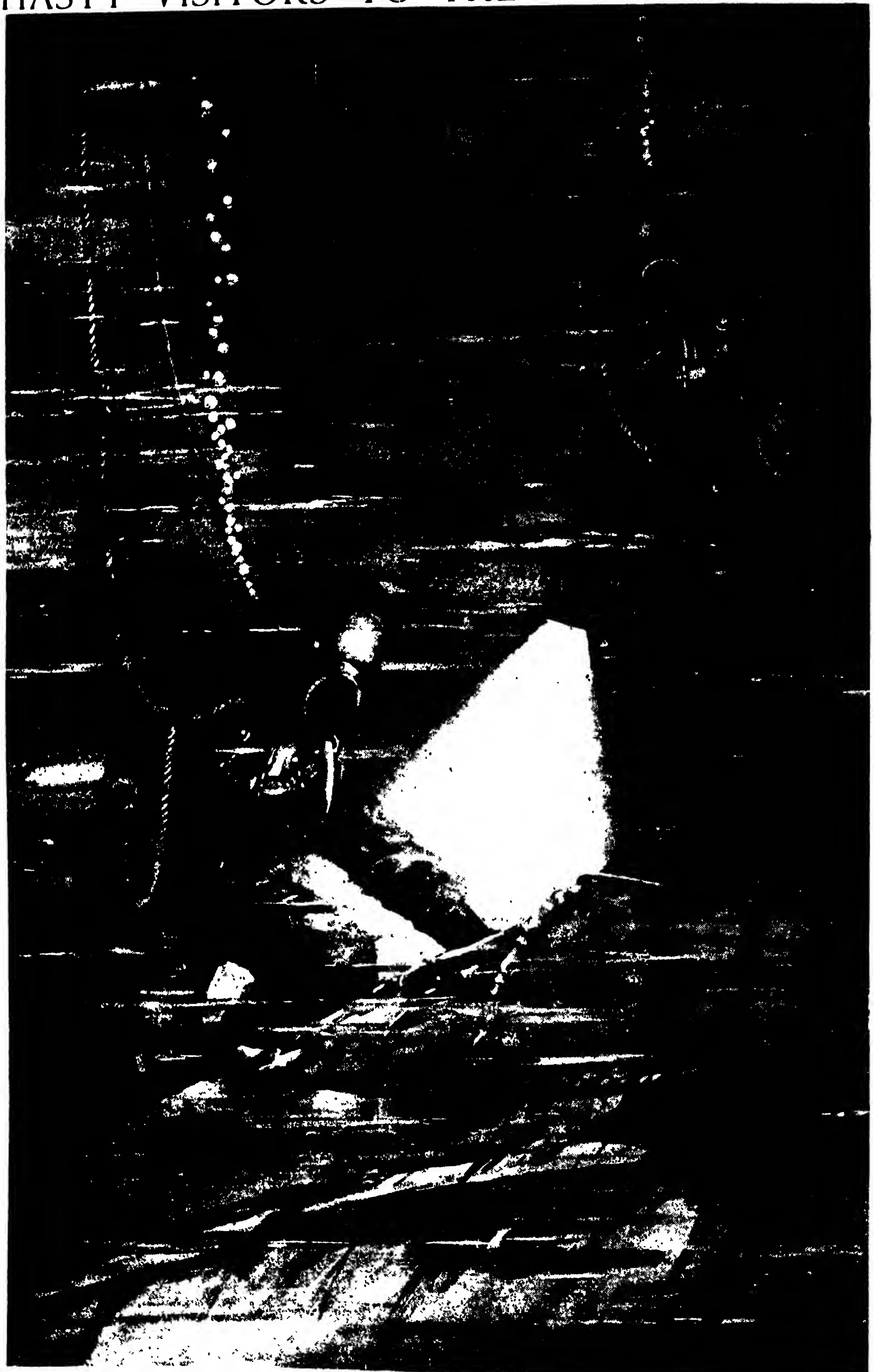
A SCENE AT THE DELHI DURBAR

OVER A HUNDRED PICTURES OF AN EXPRESS TRAIN, TAKEN AS IT FLASHES PAST





THIS SERIES OF PICTURES, SHOWING AN EXPRESS TRAIN PASSING A GIVEN POINT, IS REPRODUCED DIRECT FROM A CINEMATOGRAPH FILM



DIVERS INVESTIGATING THE STATE OF A SUNKEN SUBMARINE

Some of the pictures illustrating these pages are by courtesy of Messrs. Siebe, Gorman & Co., Ltd., the celebrated submarine engineers; others are by Messrs. Percy Collins and Stephen Cribb.

TOILERS BENEATH THE SEA

Adventures and Perils of Armies of Men Who Work in the Sunless Ocean Depths

METHODS THAT SAVE FROM DISASTER

OVER the greater part of the earth extends a weird and mysterious country that no man has ever entered. Eternal darkness covers it; it is very cold, and full of strange, beautiful life. In some places there is a tall growth of stems, eighteen feet in height, of a pale lilac colour, and a wild fairy radiance. This living cornfield waves to and fro in the slow tidal current, glowing with soft, suffused light, and sparkling and flashing at the slightest touch. Now and then it breaks into avenues of vivid brightness that indicate the path some fish has taken through this region of enchanted loveliness.

Blind, crab-like forms steal in and out of the strange undergrowth, but many of the creatures living in this sunless world shine with an inner radiance. There are living stars with green, scintillating light, sea-snakes with a white electric flame, and myriads of little forms with a rainbow-tinted phosphorescence. Six hundred fathoms from our shores lies this land of night, in which nearly every living thing emits a soft and lovely radiance. What little knowledge we have of it is of recent date, and it has only been attained by dredging the bottom of the sea.

For no diver has yet been able to descend in six hundred fathoms of water. Six hundred fathoms are three thousand six hundred feet: and the greatest depth to which a diver has descended is only two hundred and ten feet. This record was attained by Mr. Catto and Lieutenant Damant, in 1906, at the end of a series of experiments conducted by a Deep Water Diving Committee, on behalf of our Admiralty. Two hundred and ten feet, however, only takes us one-sixth of the way down the surface water of the sea, where there is enough light for seaweeds to grow. It is at twelve hundred feet that the deep sea begins, and it goes down to 31,722 feet. There are abysses in the ocean whose depth is about equal to the height of the highest mountains. At the depth of ten thousand feet are swarms of highly organised animals, some of which have rows of natural lamps along their bodies; and it is possible that the floor of the ocean there is as bright as the surface of the sea on a calm summer night, for it seems in places to be illuminated with myriads of little creatures that shine like glow-lamps. Gigantic octopuses move about like animated fireworks, and weird and horrible shapes of life haunt the black, icy waters.

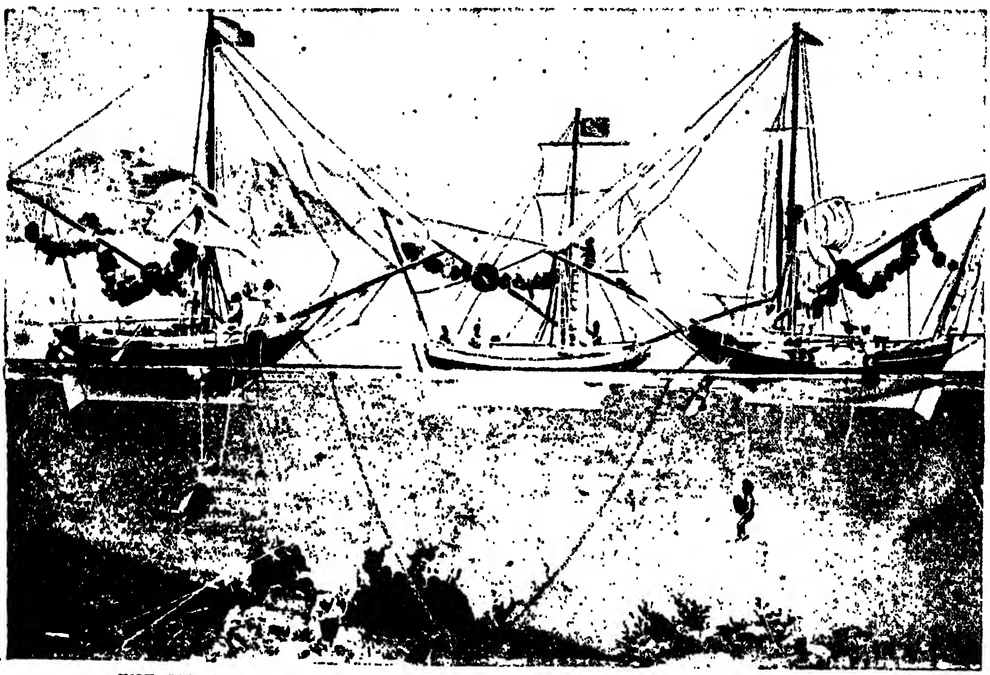
Such is the under-water world into which man has yet scarcely peeped. He has scaled the sky, and mined deep into the earth, but the sea stays him. He dare not yet descend more than seventy yards below the waves—seventy yards out of ten thousand yards! And even this little journey is accomplished at great peril. Mr. Catto barely escaped from death when he performed it six years ago. The under-world of the ocean, on the fringe of which a few daring men just venture, is surely the last kingdom of Nature that the human race will conquer. With all our progress in invention, thousands of years will very likely pass before a man stands alive in an ocean abyss as far below the sea-level as Mount Everest is above it.

In the meantime, the diver remains what he has been for three thousand years—the most romantic and adventurous of all toilers. He sees what few human beings see, and experiences what very few persons would care to experience, and he always takes his life in his hands. When he goes down naked to grope for pearls and sponges, he becomes the prey of the dogfish, the shark, and the entangling octopus. When he makes a dive of some hours, arrayed in

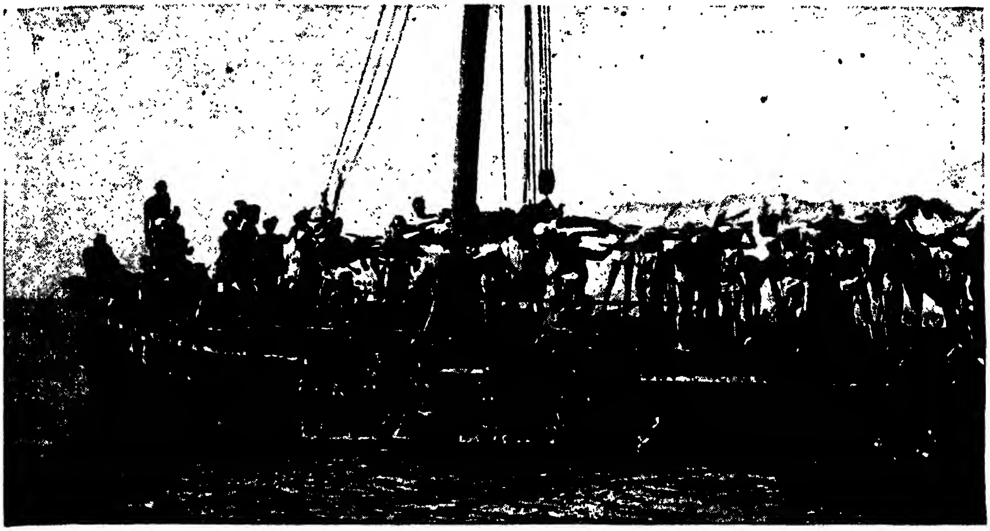
armoured helmet and breastplate and supplied with air through a long tube, his occupation is a little safer in one respect, but more dangerous in another way. He has then little to fear from the cowardly shark, but he is in great peril from a curious kind of paralysis which is known as diver's palsy. Groping in the mud of a river bottom, or crouching on the sands in the green-grey twilight of an ocean bed, he works alone—a monster-headed, awkward, hideous creature, squeezed, as if in a vice, by ton on ton of water, and clad in a cumbersome unwieldy armour which often becomes his coffin. The dress worn by the modern diver was invented by Mr. Augustus Siebe, in 1839, while engaged on the wreck of the "Royal George." Previous to that time, the best mechanical means of exploring the under-water world was the diving-bell, first designed by the famous astronomer Dr. Edmund Halley, in 1714, and improved by John Smeaton, in 1778, while building a bridge over the Tyne.

The diving-bell is now chiefly used in submarine engineering work, but even here the solitary, adventurous diver often has to undertake the most perilous part of the task. His suit is made of rubber moulded between two layers of heavy canvas, forming a material about a quarter of an inch thick. A breastplate of copper protects the lungs from the enormous pressure of water, and thus allows the diver to breathe. In the absence of the breastplate he could not expand his chest and take in air. Attached to the breastplate is a copper helmet with two glass portholes, very strongly made and protected by metal bars. At the back of the helmet is the attachment of the air-pipe.

This contains a valve that only opens downward to admit the air, and closes if anything happens to the hose. The pipe has to stand very great pressure, so strong metal wire is used to reinforce the rubber. On the ship a pump, worked by hand or power, sends the air down through the pipe to the helmet. When a diver is at a depth of two hundred and ten feet, he has to fight against so terrible a pressure of water around him that he requires seven times more air every moment than a man needs in an ordinary way. If he is also working very hard, a still larger supply of air is needed. Six men working with all their might at the pumps are often unable to give him the amount of air he needs. So he chokes to death. This fact was only clearly known six years ago, from the experiments conducted by the Deep Water Diving Committee; and its discovery has done more than anything else to save the lives of divers.

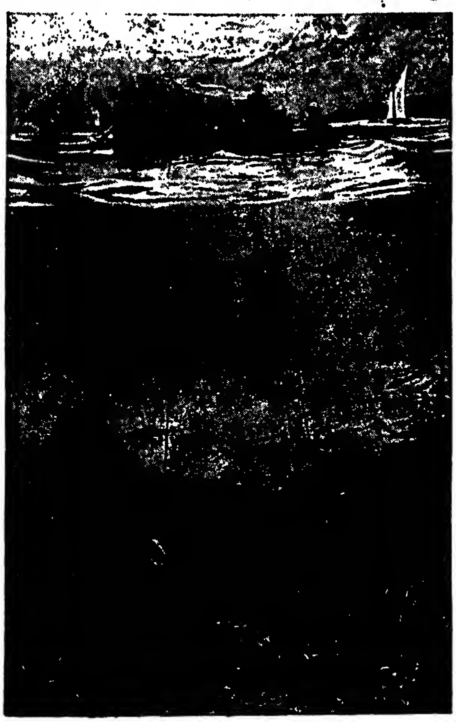


THE MODERN AND THE ANTIQUATED METHODS OF DIVING FOR SPONGES



PEARL-DIVERS GOING OVER THE SIDE OF THE PRIMITIVE BOATS USED OFF CEYLON

The surplus air escapes through a second valve on the right side of the helmet. This valve is closed by a perforated plug, and by screwing it the diver can raise or lower the pressure in his helmet and dress. Two leaden weights, back and front, weighing thirty-six to forty pounds each, and boots with thick leaden soles weighing sixteen pounds each, complete the outfit. The seventy-two pounds of lead serve the same purpose as the huge stones which naked divers carry with them when they plunge into the sea. They enable the diver to sink. Even in his armoured dress a man soon becomes lighter than the water he displaces. At, for instance, a depth of two hundred feet, the pressure of water is nearly ninety pounds to the square inch, and a diver could no more enter so dense a medium than could a balloon. He would merely float about helplessly at the level where his weight corresponded with the weight of the water. In order to reach the bottom, he has to make himself as heavy as is the sea water there.



NATIVES COLLECTING PEARLS ON THE SEA BOTTOM

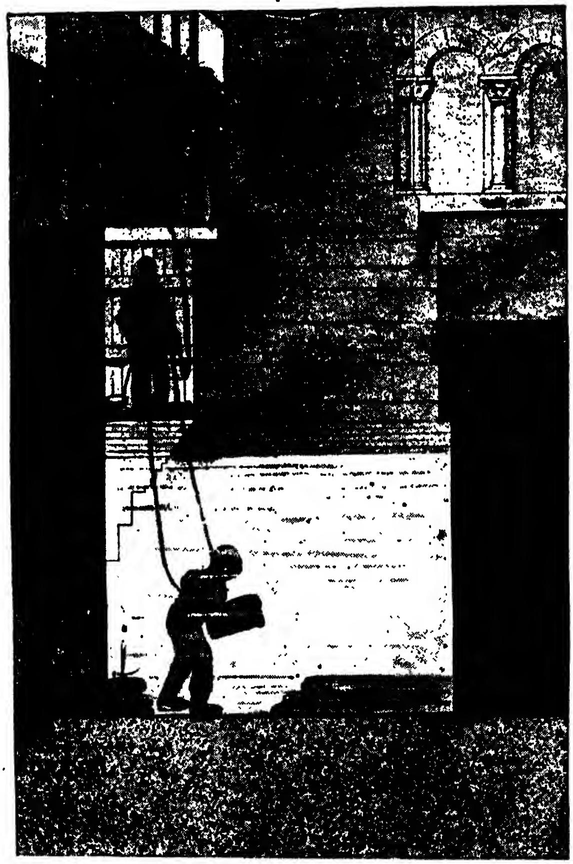
So if he is a naked diver he takes a huge stone with him; if he is armoured, he carries seventy-two to two hundred pounds of lead on his back and chest and feet.

The weight necessary in very deep diving is so heavy that the strongest man can scarcely stagger beneath it across the deck. Just before he goes over the side of the diving-boat, the face-plate is screwed on the helmet. Then the helper grasps the life-line, and lowers the diver hand over hand; and in the ears of the explorer of the under-water world sounds the click of the pumps forcing fresh air into his helmet. The click becomes part of himself. He is ever listening for it, and he starts violently at the slightest irregularity of the sound. It is a message of life sent to him by the pump, and it tells him "All is well with you, so far as we are concerned."

The diver hears the quickening of the clicks as the pumps work faster while he descends to a lower level where he needs more air to counteract the increasing water pressure. The

rapid clicks inform him that he is going deeper. So does the fading light. So does the water pressure, which forces his thick suit against him as tight as skin—except beneath the helmet and the breastplate, where his lungs require freedom. At last his feet strike bottom, and he is cut off from the world. His only means of communication is the life-line, and his messages are sent by tugging or shaking it, and are interpreted by his watchful helper. The helper pays out and takes in hose and line, continually "feeling" the man below, in the same way as a fisherman "feels" a fish at the end of the rod.

Thirty years ago, Messrs. Siebe, Gorman & Co. began experimenting with telephones for diving work. The wire was wound either round the air-pipe or passed through it. This, however, did not work well. So the life-line was made into a telephone wire. Just recently Mr. Augustus Siebe's old firm has patented a new apparatus, by means of which divers can speak to one another as well as to their helper. The telephone wire is placed in the life-line, and it is connected with a receiver and a transmitter in the divers' helmets. From the helmets the wires run through the life-lines to the battery-box on the ship, worked by the helper. The helper has a hand telephone for his own use, and on receiving a message he can at once connect the wires from two divers' life-lines in such a manner that the men can talk to one another. When a band of divers is working on some big job—recovering treasure, raising a sunken ship, or blasting rock away with dynamite to deepen a channel—the work goes on more easily and more safely when the men can talk to each other. It makes for concerted action in every emergency, and does away with the weird, oppressive sense of loneliness and helplessness beneath the sea.

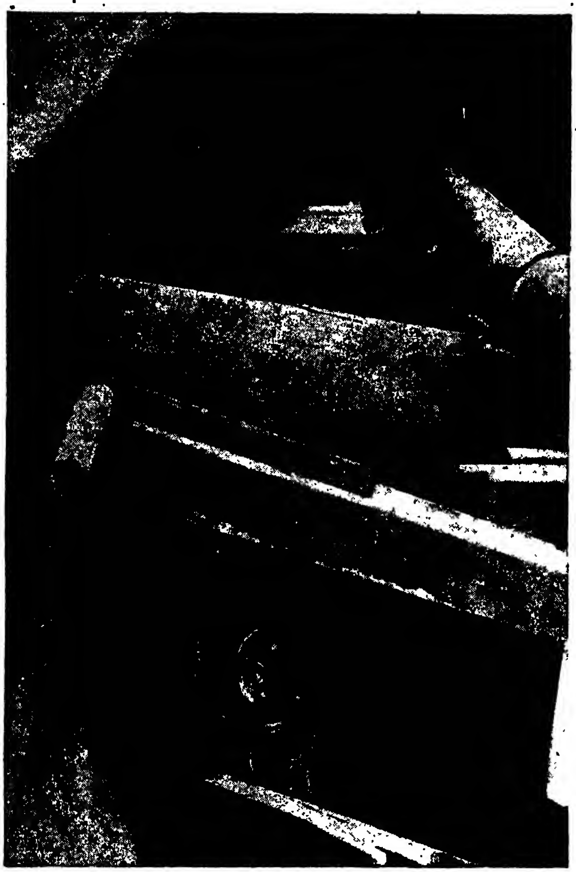


PICTURE-DIAGRAM SHOWING HOW DIVERS ARE UNDERPINNING WINCHESTER CATHEDRAL

Under the happiest circumstances the work of a deep-sea diver is extraordinarily difficult. He is strangely helpless. For, in spite of the one hundred and eighty or two hundred pounds of armour in which he is clad, he is as light as a feather. He loses that fundamental element of physical strength—gravity. So nearly equal is the balance between the weight of his body and armour and the pressure of the water around and above him that he becomes like a man on the moon. By giving the slightest spring, he can make fabulous jumps. And yet for all practical purposes his muscles and sinews are as weak as those of an eight-year-old child. If, at a depth of two hundred feet, he strikes a blow with an axe, using all his force, the blow will not break a thin piece of wood. The pressure of the water is so great that the blow is seven times as weak as it would be on land. If he uses a shovel, he dare not press the blade into the mud. If he did so, he would tumble over backwards. He must scoop the blade full with his hands, at the risk of cutting and tearing them on the sharp edges of shells and wreckage.

So helpless is he that often if he stands erect he is swept from his feet by the drag of a current or tide against his hose and life-line. If he wants to walk, he must lean forward, his body half bent to the ground, and laboriously use his hands as paddles; or he must crawl on hands and

knees, digging his fingers into the ooze like a gigantic mud-fish. The five senses of a diver are strangely impaired when he is working in the mysterious kingdom of the sea. He smells nothing except the odours sucked in by the pumps far above him; and with these odours mingle the smell of the rubber of his air-pipe and the smell of the machine oil used in the cylinders that are clicking air down to him. His powers of hearing are curiously altered. If the guns of the "Orion" went off above his head, he would not know what had happened, except by the quake of the mud beneath his feet. On the other hand, submarine noises come to him through the escape valve in his helmet. He can hear an under-water explosion three miles away, and the thumping and stamping of submarine drills more than a mile off are distinctly audible. And he can hear the grating and grinding of splintered spars and timbers moving in the grip of the current on the deck of a sunken hulk.



DIVER DESCENDING TO WORK ON THE FOUNDATIONS OF WINCHESTER CATHEDRAL

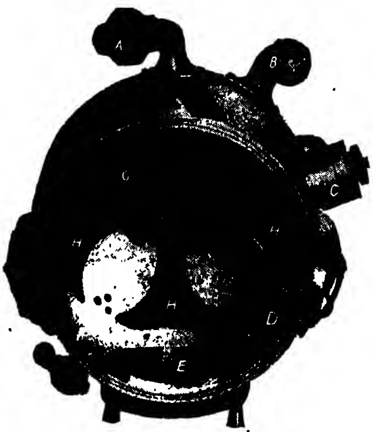
When he is in clear water on a sandy bottom, he finds himself in a green-grey haze of twilight, which limits his field of vision to ten yards at the most. Gazing upwards, the sunshine comes to him in a magnificent golden inverted cone, beaded with myriads of tiny silvery bubbles, like fizzing champagne. Everything around him is weirdly distorted and magnified. The crabs and lobsters and slow-moving fish that he can catch at will appear in large and wild shapes. The tiger of the seas, the shark, looms as big as a small sailing-yacht. This monster could easily take the leg off a diver in full armour, but happily it is a coward, and, frightened by the strange appearance of the diver, it flees from him. In the old days, the pearl-fishers of Ceylon and Australia, and the sponge-divers of Tripoli worked in terror of the shark and the dogfish. They dived naked, with merely a life-line, a heavy stone, and a net, and they seldom remained under water for more than a minute.

Tales there are of Ceylon divers who acquired by practice the art of remaining under the water for a quarter of an hour, but these tales are utterly false. Two or three minutes is the limit of endurance of the most skilful diver who has no mechanical means of supporting respiration. These men suffer severely from the continual effort of holding the breath, and bloodshot eyes and effusions of blood from the lungs are common among them. It was the shark and the dogfish, however, that drove the pearl-fishers and the sponge-fishers to profit by the invention of Siebe, and most of them now wear a good diving-dress.

For three thousand years the natives of Ceylon have fished for pearls, and their skill in diving is handed down from one generation to another. The pearl oysters are found in the Gulf of Manaar, and the fishing season is opened in March or April, in certain years, when sample oysters, tested by a Government official, show that pearls are present. News that a fishery will be held spreads with extraordinary rapidity not only through Ceylon, but through the whole of India and Malaysia, and up to the Persian Gulf. The result is that forty-five thousand people quickly gather for a single month on the desert shore; and a shanty town springs up, with streets of huts made

of bamboo poles, roofed with palm-leaves. The sea is covered with vessels of all shapes and sizes, and the divers stand ready for the plunge at the firing of the signal gun. The oysters are sold unopened in small lots to humble speculators, who trust to luck that they may obtain a crop of gems. The diver usually gets a third of the value of his catch. About a quarter of a million pound's worth of pearls is obtained in a good fishing month.

At the pearl fisheries of Australia, Malays and Japanese are employed. In this industry the pearls are only of secondary importance. It is the trade in mother-of-pearl which is the staple. The gems, which the oyster forms round the larva of a tape-worm, are merely an exciting gambling element in the fisheries. What is needed on the magnificent oyster-beds that stretch from Port Darwin to Cossack is scientific management under Government control, such as has revived the pearl fisheries of Ceylon. At the present day, sometimes not a single pearl is found during the whole season; and the Australian skipper and his crew of Malays, with a diver who usually comes from Manila or Japan, merely collect pearl shell. Mother-of-pearl fetches a good price, and the Australian pearl-fishing fleet is fairly prosperous. But a couple of men of science could probably make the oyster beds that extend for a thousand miles along the coast of North-West Australia as rich in pearls as those of Ceylon.



INTERIOR OF A DIVER'S HELMET

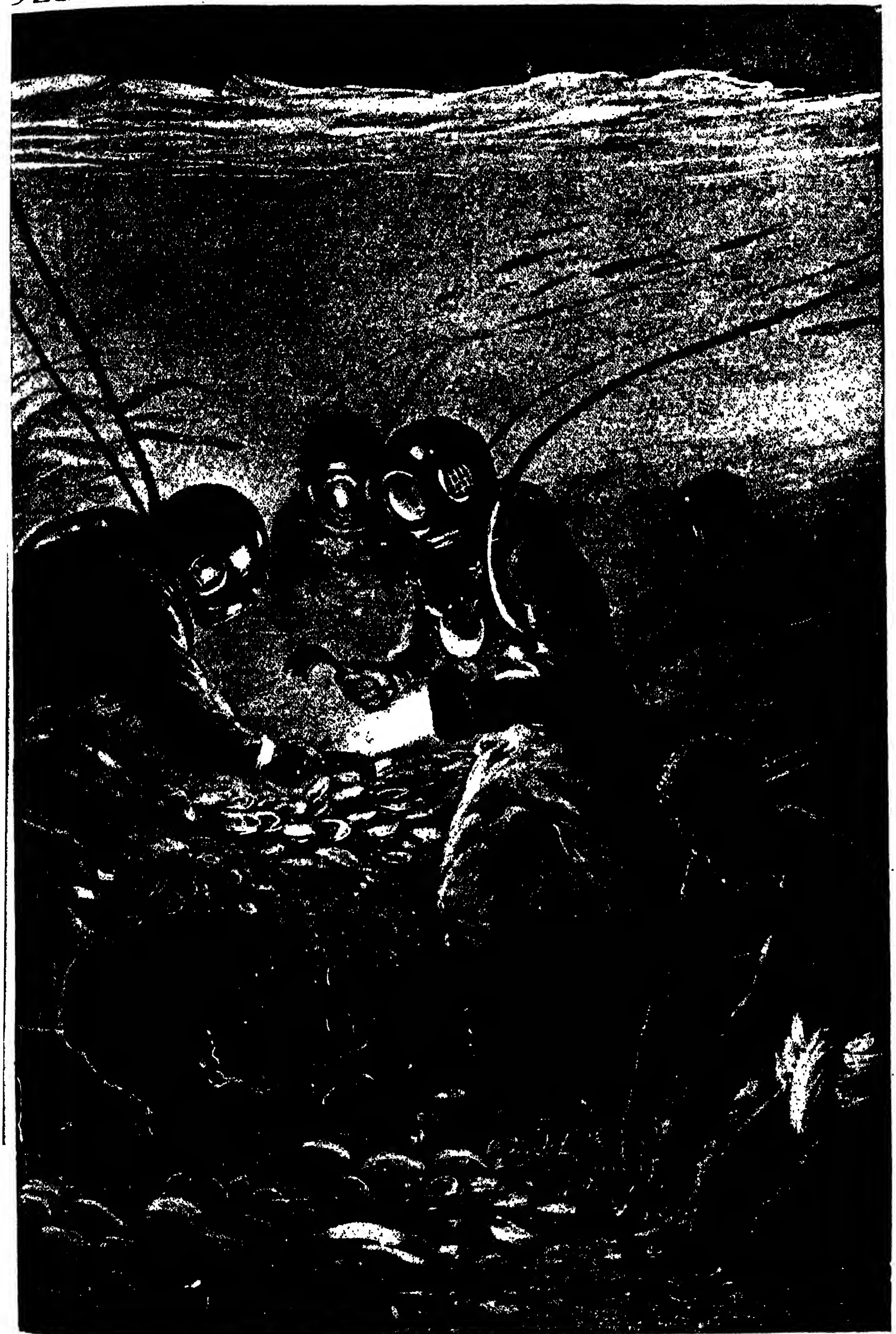
A, air inlet valve; *B*, telephone connection for the cable; *C*, regulating outlet valve; *D*, telephone transmitter; *E*, chin contact for ringing bell at other end: *F*, ring for attaching helmet to corselet; *G*, telephone receiver; *H*, airways from inlet valve with outlets over view-glasses.

The Australian diver seldom goes more than ninety feet below the waves. The richest beds he cannot touch, and even a few seasons' work at the ninety-foot level ends his career. This shows again a lack of scientific management. With a proper air-supply, and a proper method of bringing the diver to the surface, there should be no difficulty in working on the very lowest beds with no danger to health. It is true that the sponge-fishers of the Mediterranean suffer terribly from diver's palsy—the same complaint that kills or maims the pearl-divers of North-West Australia. But the experiments of our Deep Water Diving Committee have now made diver's palsy as rare among Admiralty divers as death from a shark bite. It is an easily preventable disease; and gross ignorance or gross carelessness on the part of the men who handle the pumps and raise the diver is alone responsible for it.

It used to be considered that the enormous pressure of deep water was the direct cause of diver's palsy. It is now known that this is not so. The disease is produced by the excess of nitrogen gas taken into the system while breathing compressed air. Men who work in compressed air in diving-bells and caissons are also troubled with an excess of nitrogen. No pain is felt, and no injury is done while they continue to breathe the compressed air. If, however, they are suddenly brought into an ordinary atmosphere, the excess of nitrogen escapes in the form of bubbles. It is these bubbles in the tissues and blood, which are called "bends," and produce the strange pains. When the bubbles form about the heart death at once occurs; when they collect about the nervous centres, paralysis takes place.

It is sometimes a quarter of an hour after a diver has been lifted out of the water that he falls dead or becomes paralysed. All that is necessary to prevent any ill effect is to "decompress" him. This is done by lifting him very slowly through the water, allowing him to stop for some minutes at various stages in the upward journey. An hour and a half, for instance, is needed in raising a diver who has been working for a considerable time at a depth of two hundred and ten feet. The nitrogen gas then escapes slowly, without making any bubbles in the body of the diver; and when he is lifted on the ship and stripped of his dress he is as healthy as an ordinary man.

A DIVER'S WEIGHTED BOOT



Pearl-fishing is now partly carried on by men in divers' outfits, but many natives, who still hold their breath while diving, are sunk by a heavy stone, and have their nostrils closed by a tight clip.

The neglect of proper methods of decompression shortens the lives of many pearl-fishers and sponge-divers; and sometimes the pumps are not worked at the proper speed to provide them with an air-supply equal to the pressure of the water. The actual work which they perform is much less dangerous than that which wreck-divers accomplish.

It is the wreck-diver who descends to sunken vessels to recover lost treasures, or to repair the holes torn in the hull by rocks, so that the ship may be raised by the cables that he places under it. Sometimes he goes down with an axe and lamp and some dynamite cartridges, and cuts a vessel into huge sections, as clean as if the divisions had been done by a giant's chisel. Having cut the ship up, he again descends, and over him hangs the one-hundred-ton arms of some immense hoisting contrivance. He fixes the arms to the cable he has bound round the wreck, and so bit by bit the dangerous wreck is removed, leaving a clear passage for other ships.

A DEEP-SEA DIVER AND HIS COMPLETE EQUIPMENT
This picture shows a diver ready to descend, with the air-tube and the signal line, containing the telephone wire, attached to his helmet. He is armed with a knife, and carries a self-contained electric lamp.

One hundred and eighty-two feet is the greatest depth at which a diver has been known to work at treasure-seeking. This depth was attained by a Spanish diver, Angel Arostarbe, who recovered £9000 in silver bars from the wreck of the steamer "Skyro," sunk off Cape Finisterre. But the most famous of all divers is Alexander Lambert, who salved £70,000 from a Spanish mail steamer, "Alphonso XII.," that was lost in one hundred and sixty-two feet of water off Las Palmas, Grand Canary. Much larger sums have been recovered, but the exploits of Lambert and Arostarbe are remarkable for the great depth at which the work was performed.

A strange ship lying on an even keel in broad daylight is difficult enough to explore, but a strange ship, fallen topsy-turvy, with its decks inclined at a steep angle, the hull half buried in mud, and with the deep waters of the Atlantic weighing upon it, is a different matter. It lies in inky darkness, battered, littered with débris, and with innumerable corners and splintered spars and timbers ready to foul the air-pipe or life-line of the adventurous diver. A slimy, slippery ooze covers everything and adds to the difficulty and peril; and perhaps strange ghostly phosphorescent eyes and forms glimmer amid the muddy wreckage. A diver always carries a strong knife in case of attack; and in exploring a wreck, and seeking for the treasure-hold, he uses a strong lamp and an axe. And sometimes another diver, or a group of divers, comes down to assist him. The assistants form a human chain, each guiding the hose and line of the man forty or fifty feet ahead of him. The leading man then goes ahead and makes his way into the wreck, knowing that his air-pipe and life-line are being carefully guarded. By reason of his air-pipe and line, he must always leave the ship by the way he entered it, constantly telephoning to his helper about the management of his hose and life-line. If either of these gets fouled and cannot be cleared, the diver dies. In one of the experiments of the Deep-Water Diving Committee, Mr. Catto fouled his line, and could not clear it for twenty minutes. He was two hundred and ten feet below the level of Loch Striven, and the pumps on H.M.S. "Spanker" could not be worked quickly enough to supply him with the air he needed in the sudden and violent

exertions he made to save his life. But, though choking to death, he continued the struggle, and succeeded in getting the line clear of the hawser round which it was entangled. Then an hour and a half had to pass in gradually lifting him through the water and decompressing him, but this was done so carefully that his health was not injured.

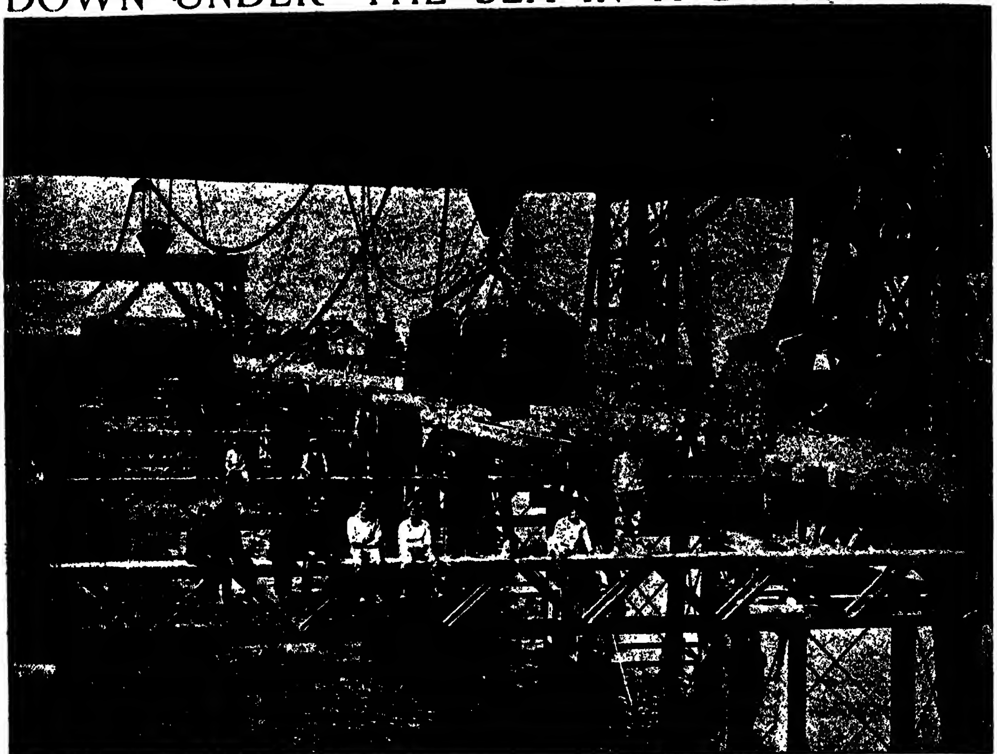
Besides working in the sea in recovering treasure, and raising ships and repairing them, the wreck-diver often has strange tasks to perform on land. Recently one of them has been working in keeping Winchester Cathedral afloat. This ancient edifice is built on a bog, and it began to sink and split in two, curiously like a wrecked ship. But the diver has now gone down into the bog with bags of cement, and converted the quaking ground into a concrete foundation.

THE USE OF THE DOUBLE TELEPHONE IN DIVING
This picture-diagram shows how the man in charge of diving operations can telephone to two divers working below. He can also connect up the wires so that one diver can talk to another while under water.

The most remarkable of all diving achievements was the historic dive of Alexander Lambert through the workings of the Severn Tunnel. While the tunnel was being built, water suddenly broke in, and the retreating workmen forgot, in their haste, to shut a certain valve. No effect was obtained upon the water by the use of the most powerful pumps. So Lambert was called in to attempt to shut the sluice. He had to walk a thousand yards, under a head of water of thirty feet. At the end of this strange journey he had to go behind an iron door in a head wall, and shut down a flap valve on an eighteen-inch pipe. After this, he had to return through the door, lift up two tram-rails, and then shut the door, and screw down a valve on another pipe. The distance was too far for one diver to drag behind him his air-pipe. So Lambert took two assistants with him. They worked as they would on a wreck.

PHOTOGRAPH TAKEN IN A DIVING-BELL SIXTY-FIVE FEET BELOW THE SURFACE OF THE SEA

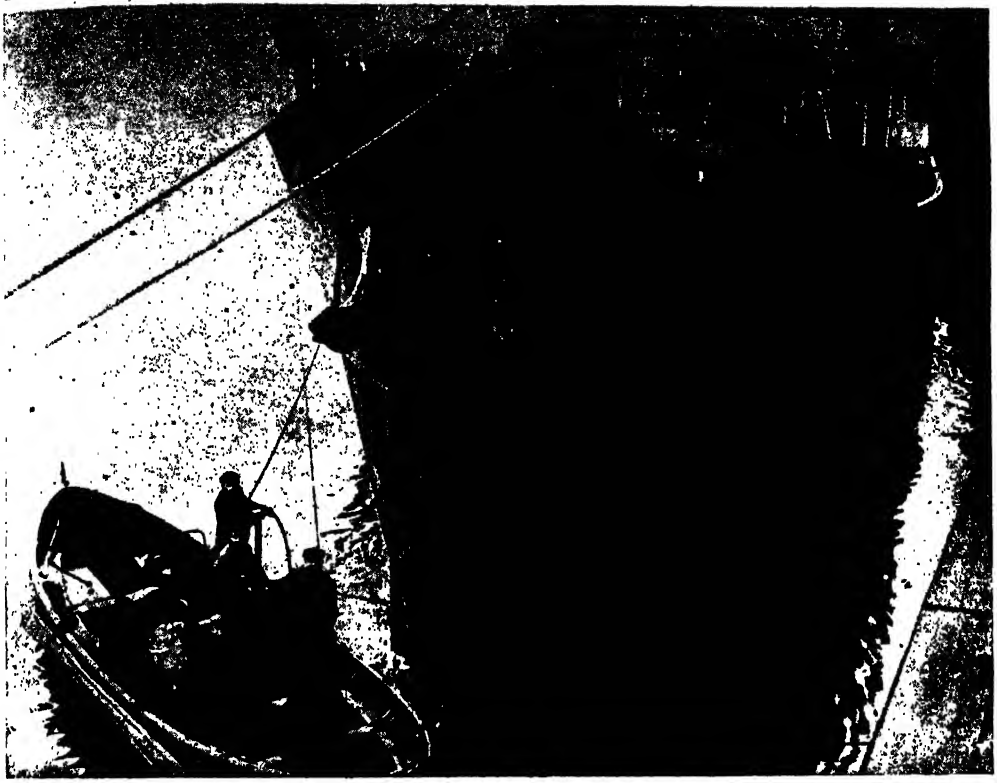
The three men went together as far as they could, dragging their air-pipes behind them. Then one stopped, and helped the other two by pulling forward their hoses. When the weight of the pipes under the water became too heavy, the second man stopped, and Lambert went on alone, with both of his assistants pulling along his air-pipe. Even with their help, however, he could not reach the door, and he had to return.



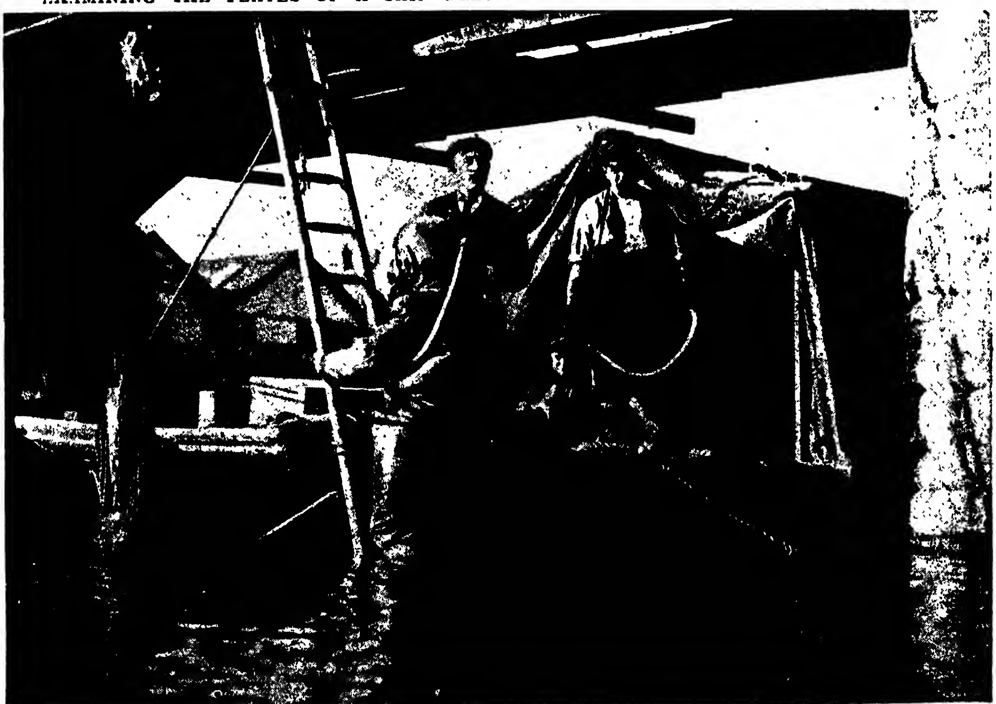
TWO 35-TON DIVING-BELLS USED IN THE CONSTRUCTION OF THE DOVER HARBOUR WORKS

A PLUNGE INTO THE SEA OF TWO DIVING-BELLS USED IN FOLKESTONE HARBOUR EXTENSION WORKS

THE EXPERT DIVER'S VARIED TASKS



EXAMINING THE PLATES OF A SHIP BELOW THE WATER-LINE AFTER AN ACCIDENT



THE ASCENT OF A DIVER WHO HAS BEEN EXAMINING THE FOUNDATIONS OF A BRIDGE.

Quite a special industry is carried on by the salvage firms that employ divers to bring up the steel, copper, and iron plates of wrecked vessels, as is here pictured.

In his second attempt, Lambert went alone, without an air-pipe. He carried, instead, on his helmet a steel cylinder containing oxygen at a pressure of 120 atmospheres. The oxygen was admitted to the helmet by a valve; and the poisonous carbonic acid gas produced by the diver in breathing was absorbed by caustic soda contained in a knapsack. This apparatus was invented by Mr. Fleuss, and it is now chiefly used by rescue parties after explosions in mines. By means of it they are able to go with perfect safety through deep underground passages filled with the deadliest of gases.

BLUEJACKETS TELEPHONING AND PUMPING AIR TO A DIVER

On his second attempt, Lambert got as far as the door and pulled up one rail. But his hands were so numbed with the cold, after travelling through icy water for a thousand yards, that his strength was gone. Two days afterwards Lambert set out again, and he was absent only an hour and twenty minutes. In that time he travelled two thousand yards under water, pulled up the tram-rails, opened and entered the door, and closed the chief valve, and screwed the other valve down as directed. This marvellous engineering feat, accomplished alone, and the saving of £70,000 worth of gold from the wreck off Las Palmas, are Alexander Lambert's titles to fame. But his work killed him. In recovering the gold he descended thirty-three times to a depth of twenty-seven fathoms. He went down twice or three times a day, and stayed from twenty to twenty-five minutes below. But in his last descent he remained forty-five minutes, and became completely paralysed in the lower part of his body, and never recovered.

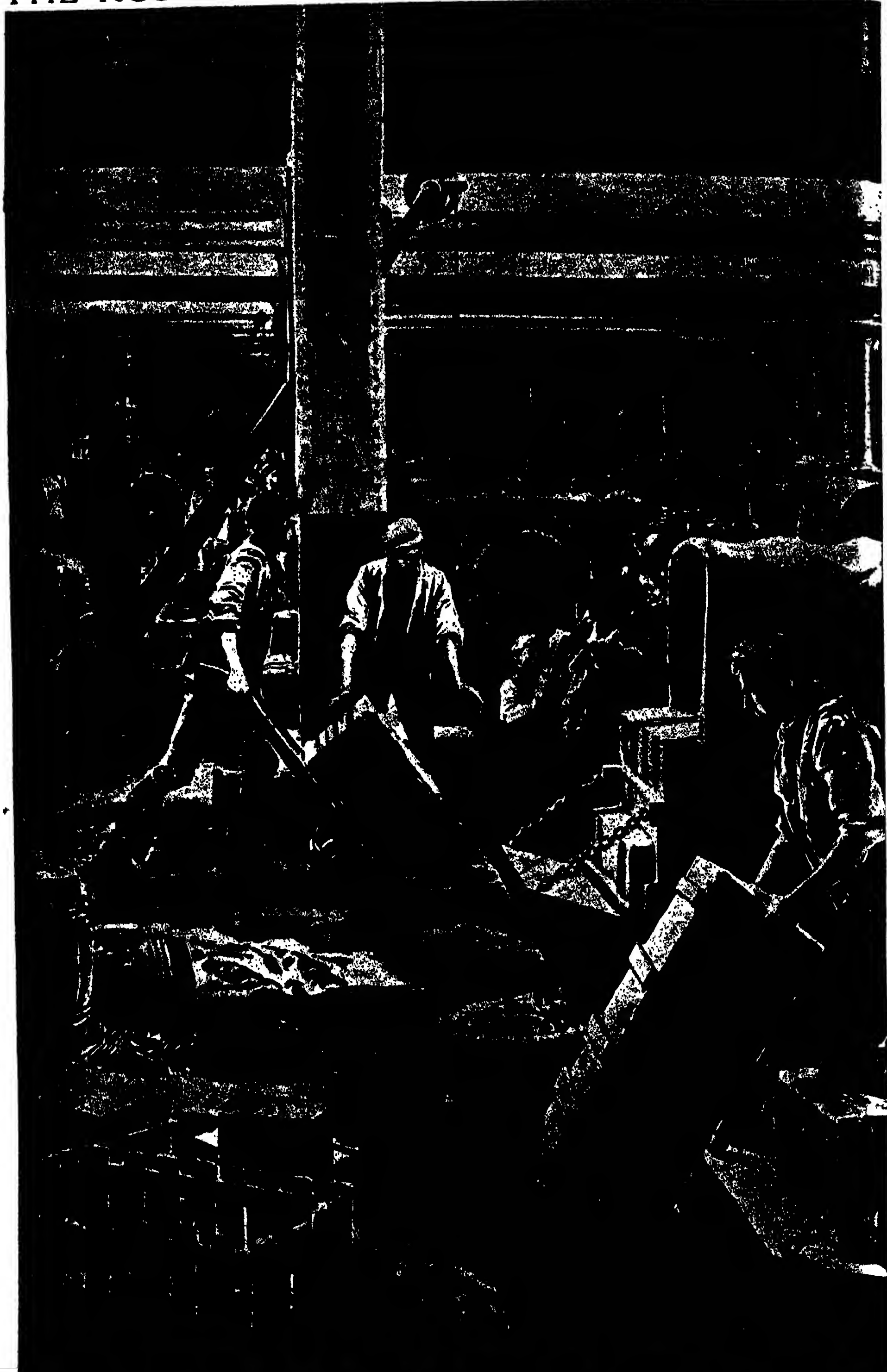
"BLOWING UP," A DANGER TO WHICH DIVERS ARE LIABLE

By manipulating a valve wrongly a diver may rise rapidly to the surface. In such a case the man has either to be sent down to the depth at which he was working and drawn up gradually, or be placed in a compression chamber.

It was the nitrogen bubbles in his tissues that injured him. But now that the Deep Water Diving Committee has worked out the method of decompression, the deep-sea diver need no longer work under the haunting fear that sooner or later he will be killed or palsied. It is now possible for a man supplied with the proper amount of air to stay for a short time 400 feet below the waves, without much risk; and it is thought that he could stand two or even three hours' pressure at a depth of 300 feet.

These calculations have been worked out by actual experiment in a tank at the Lister Institute, in which water can be compressed by engine-power to an enormous extent. It was by first sitting in this tank under an enormous pressure of water that Mr. Catto and Lieutenant Damant learned to make their great dives of 210 feet in Loch Striven. But other experiments, conducted by Dr. Haldane, show that, with the best apparatus at present available, human beings cannot hope to descend more than about 140 yards below the sea and come up alive. Perhaps it is from the window of a submarine that we shall be able to study the fields of lilac light and the shapes of flame in the mysterious kingdoms of the ocean.

THE RUSH TO LOAD A NIGHT GOODS TRAIN



The above scene—an incident in our stupendous national traffic—represents the goods warehouse at the Marylebone station when the day's collection of goods in London is being hastily entrained.

TRADE AND THE ROAD

How Railways, the Life of Modern Land Commerce, have Changed the Face of Civilisation

THE ILLIMITABLE HOPES OF PROGRESS

COMMERCE has ever been dependent upon such roads as the engineers could make for it. In the last chapter we saw how the great open road of the sea has been made available for man—chiefly in modern times by the work done in British shipyards. The great waters either divide or connect the peoples of the world. Without science, they divide and divorce; with the aid of science they connect and espouse. We pass from the high seas to the consideration of the equally important tracks and highways with which man has reticulated the land area of the globe.

Civilisation and the road have always gone together. The wonderful engineering works of the Romans still exist, and will remain while man remains upon the earth, a tribute to the wisdom as well as to the courage of their constructors. It was the Roman road which largely helped to sustain Roman power during so many wonderful centuries. It is the glorified road of modern science which has given mankind a new mastery of the world, and which, in combination with the exercise of similar powers upon the seas, has given a new meaning to the word Commerce.

Indeed, when all is said as to the work of men in other fields, it is the engineer and the scientist who stand out as the pre-eminent re-builders and re-creators of civilisation. The arms of the soldier, the deep thinking of the philosopher, the lofty aims of the statesman, are all alike subsidiary to the forces invoked and yoked by science. The methods of warfare and the nature of campaigns are revised, the food for thought is sown, the possibilities before the statesman are changed in nature and direction by the new control of Nature which is the gift of science to the world. The commerce of the eighteenth century is an idle tale in comparison with the gigantic interchange of commodities which has become an unrealised commonplace in the twentieth century.

And there is a very important distinction to be drawn between the old commerce that existed before the modern scientific era and the new commerce of our time. It is that, before power had been harnessed by the engineer, the methods of commerce were far ahead of the means of prosecuting it, whereas to-day the very reverse is the truth. The present position is that the machinery of transmission, the power to transport commodities, whether by land or sea, is superior to commercial method.

We have already noted the intimate connection between the British possession of coal-mines and the great British inventions which revolutionised industry, commerce, and the world. The steam-engine was devised without conception of what it would do for industry. The immediate purpose was to pump water out of our coal-mines to enable us to get at our precious coal. Similarly, the locomotive was invented without conception of what it would do for the world. Those who worked at it were chiefly mining engineers, faced with the difficulty of hauling that bulky and weighty substance, coal. Trevethick and George Stephenson, it must be remembered, were both intimately connected with mining operations.

It is exceedingly difficult, in looking back upon the origin of certain inventions, to decide the real degree of genius possessed by their originators. The connection of even moderately ingenious minds with a great necessity is bound to produce effective results. The probability is that thousands of latter-day minor inventions demand fully as much, if not more, skill and ingenuity than a number of the primary inventions, such as the conception of movable type,

or the use of a smooth rail for traction, or the idea of the piston, or the conception of the multi-tubular boiler—all of them ideas of a very simple order. We are naturally apt to glorify the character of an invention by the magnitude of its results, and some of the simplest inventions have had enormous results.

George Stephenson took the elementary locomotive of Trevethick and made it very much the steam locomotive that we know to-day, but which we shall not know very much longer. The steam locomotive, indeed, is already obsolete, although, unfortunately, its departure is exceedingly slow, owing to the vast amount of capital sunk in steam traction. With Stephenson's perfecting of the steam locomotive, the railway began its triumphant career. The competition in which Stephenson's "Rocket" was triumphant took place when nearly one-third of the nineteenth century had already elapsed. That is to say, the history of modern railways is not yet ninety years old. What marvels have been accomplished in that brief fraction of the world's recorded history!

Early Railway Enterprise, and the Long Start of the British Race

The first passenger railway was the Stockton-Darlington, which was opened in 1825. Then came the Liverpool and Manchester Railway in 1830. Continental nations were quick to see what a mighty thing had been discovered. In 1833 France, and in 1835 Germany, entered upon railway schemes. Belgium employed George Stephenson himself upon Government lines; and it is intensely significant to observe that as early as 1844, four years before the death of Stephenson, the "Quarterly Review" pointed out to the British people that railway fares in Belgium were only one-half as great as in the land which produced Stephenson. The United States got to work soon after the Stockton-Darlington Railway was opened, and in 1830 a steam line was at work in Carolina. By 1840 the United Kingdom had 1800 miles of railway, but the United States had forged ahead with 2800 miles. As for the rest of the world at that time, Germany had about 300 miles, Belgium 200, Holland 10, Italy 13, and there the list almost ends. Ten years later, however, the figures had grown greatly. In 1850 the United Kingdom had 6600 miles, the United States 9000, Germany 3600, France 1900, Belgium 550, and many other countries had made a fair start. Thenceforward the iron rails advanced at an ever-accelerating pace.

We can obtain a very fair picture of the world's progress by measuring the growth of its railways. In the table on page 1601 we show the advance of Europe, which now possesses about 200,000 miles of line. It will be seen that no less than four European nations now own larger railway systems than the country which invented railways. This, of course, is largely due to their areas. Germany, France, Russia, and Austria-Hungary are all of them far larger countries than the United Kingdom, but when this is said it is impossible to be altogether pleased with the recent slow growth of the British railway system. That is a point of much importance to commerce, and we will return to it presently. Beside the five countries already named, only one other—Italy—possesses over 10,000 miles of railway.

Our Cessation of Enterprise and Remarkable Loss of the Lead

The growth since 1850 is shown in this statement as measured at intervals of twenty years, although it has not been possible to give complete figures for all European countries later than 1908. We see that in 1850 Europe could boast of only about 15,000 miles of railways. Twenty years later the length of line had quadrupled. In 1890 the figures of 1870 had been doubled. Even in the eighteen years since 1890—a date which to many of us seems but as the other day—some 60,000 miles of European railways have actually been built, to which the United Kingdom has contributed only 3000.

When we turn to Asia—to an area exceedingly greater than that of Europe—we get very different figures. In 1908 all Asia boasted only about 45,000 miles of line, and of these all but 15,000 were in British India, and almost the whole of the balance in Russia and Japan. It would have been well for Russia if she had not postponed so late the building of an iron road across Asia. Japan has multiplied her railways fivefold in the last twenty years.

The Railways of the World Due Almost Entirely to European Initiative

The Chinese railways have grown through the speculations of foreign concessionaires, but her enormous territory is for the most part just as it was before men had seriously begun to experiment with steam. The Asian record most significantly contrasts with that of Europe in the statement. If we turn to the nation in Europe which is only

nominally European—Turkey—we see that the record of its railway progress is very much the same as that of Asia unassisted by European hands. Almost the whole of the Asian railways are European in origination. Only the few thousand miles of Japan can be said to owe their building to Asiatic enterprise.

As to Africa, when we remember her enormous area we see how comparatively insignificant are the developments which have yet taken place. They are almost entirely confined to British South Africa and to Egypt. The newly made Union of South Africa has over 7000 miles of railway, which is excellent, and Rhodesia has already over 2000 miles. Very significant is the fact that Egypt has a mileage of about 1500. Egypt is still nominally part of Turkey; and the fact that her railway mileage is so much greater than that of the Sultan's dominions is, of course, conclusive evidence of European control. Even if we did not know the historical facts, we could gauge them from the railway evidence. All the world, and every race, gains by the white man's work.

We come next to America, which has more railways than all the other four continents put together.

The Enormous Growth of Railways in the United States and Canada

As the head of the list, of course, the United States stands easily supreme. Her vast area of 3,600,000 square miles is now covered with a network of railways which will soon have a mileage of two hundred and fifty thousand. It may be pointed out that it is this great call for railways by a naturally rich land which has stimulated the enormous growth of the American iron and steel industry, no small part of the trade of which is concerned with furnishing the materials of American railroads, whether for new construction or for repair. The Canadian lines have already a very creditable total, which have already out-distanced that of the Mother Country. Mexico, Argentina, and Brazil have all more than ten thousand miles of railways. The growth of American railways as a whole, especially in the last twenty years, again reminds us of the stupendous possibilities of the lands which Columbus revealed to the world. In Europe there are only six nations with more than ten thousand miles of railway; in the American continent there are already five countries with such a mileage, and before the lapse of another twenty years there may easily be many more.

In Australasia the enterprise of European peoples has already constructed nearly twenty thousand miles of railways, bringing up the total for the whole world to about 580,000 miles.

From one point of view this is a magnificent total, but the future, and not a very remote future, will make the aggregate of 1908 seem very small indeed. It is only in Europe and in some parts of America that railway work has been yet seriously accomplished, and even in Europe there is room for exceedingly large developments.

The Limitless Possibilities of Expansion for British Trade

It is well to remind ourselves of these facts, for to a nation like the United Kingdom, which, as we have seen, exists by virtue of foreign commerce, the potentialities of world trade expansion mean the possibility and probability of future growth. We get a vision of a world of almost limitless possibility, that is not a market of definite dimensions in which, as trade competitors grow, we must necessarily suffer, but a world that, for practical purposes, is a market likely to expand with such rapidity that in spite of increase of trade competition the opportunities of the British exporter are growing, and not diminishing, year by year. This is a great and an encouraging truth, and it ought to be more widely realised. It explains why, although in recent years the foreign trade of other countries has increased tremendously, British trade has risen to higher and higher levels. We are not dipping into a bag that contains so much and no more; we are obtaining more and more from a supply that is increasing at an ever-accelerating pace, and is likely to increase.

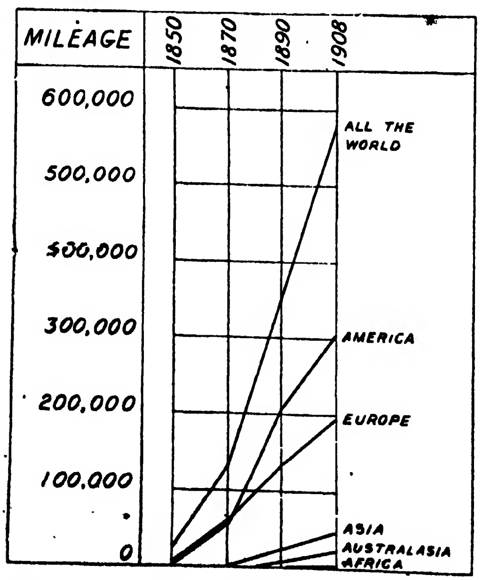
The Increase of Our Trade Consistent with the Increase of the Trade of Other Countries

In the year 1911 British exports rose to the unparalleled figure of £454 millions, *which is an increase of £163 millions upon the figures of so recent a year as* 1900. It is not too much to say that not the most gifted and intelligent of observers at the opening of the twentieth century would have ventured to predict such an amazing growth in the near future; indeed, few would have believed it possible. Now we have the accomplished fact before us; and it is rendered all the more significant by our knowledge that the commerce of Germany, the United States, France, Belgium, Italy, Russia, America, Canada, Argentina, and other places has also advanced as never before.

The important statement on page 1601 gives us a clue to what has been happening in the world at large. It may be summed up by saying that man, after all the centuries of recorded history, is only just beginning to feel his feet in the world, and to develop the world with the tools of Science. It is but the margin of possibility that has yet been touched. When we glance from the railway figures of 1850 to those of 1870, and from thence to 1890, and then on again to the records of our own time, and when we see railways beginning to stretch across and to conquer vast areas as yet almost without populations, we can afford to cherish with confidence illimitable hopes for mankind, and not less for our own country. There is an enormous part yet to be played in the world by the white man; and there is no more need now to consider British trade or British industry past its prime than when the famous "Rocket" steamed along in triumph in the Rainhill competition of 1829. As 1829 is to 1912, so is 1912 to a date, not by any means removed by a time as long as eighty years, when the world will be producing and exchanging a bulk of commodities proportionately as great or greater than the world's output in 1912.

RAILWAYS AND COMMERCE

This diagram exhibits the growth of the world's commerce, industry, and civilisation by measuring the marvellous growth of the world's railways. In the next twenty years progress is likely to gather acceleration.



The economic importance of a railway is so intimately bound up with national development that by far the greater part of the nations of the world have decided that they must be controlled by the responsible Government of the State. Indeed, it is easier to name the countries in which railways are still privately owned than to catalogue those which have not adopted nationalisation. In the British Empire, Canada stands out as the only colony which adheres to private ownership; throughout the rest of the Empire the railway is not only a public road but it is emphatically a national road.

With regard to foreign countries, the only great exponents of private ownership in railways are the United States of America and Argentina. France very wisely mapped out a geographical and logical railway system at the beginning, and granted to private speculators concessions only, and not ownership rights. Consequently, the whole of the French railways will revert to the State within the next generation. Moreover, in spite of this falling in of a magnificent property, which will put the French nation in an excellent financial position, the French Government nationalised the Western Railway system in 1908, and now owns nationally over 6000 miles out of a total mileage of about 29,000.

The approach to universality in the national control of railways has naturally arisen from the functions of railways. The fact that a road has rails upon it makes it not less a road, but more a road; and who would dream of leaving roads to private construction and ownership? Our ordinary roads are built and maintained at public cost, which means that we pay to walk on them just what it costs to maintain them, and no more. If we try to imagine what life would be like, and what petty trade would be like nowadays, if we had to pay interest and profit to private owners for using them, we realise what the private ownership of railways means to the trade and activities of a country. No one who has given attention to the facts can doubt that the wisdom of German statesmen in creating a great national railway system has had much to do with the progress the Empire has made in the last forty years.

As long ago as 1852, Prussia took the first step in railway nationalisation, but it was in 1880 that she seriously made her system national. Between 1880 and 1887 nearly all the private lines were bought out, and a vigorous policy of State construction

embarked upon. Of the existing Prussian railways, which have a mileage of over 22,000, more than one-half have been actually built by the Prussian Government. Taking Germany as a whole, out of the 36,000 miles of railroads within her borders, only about 2000 miles are in private hands.

It should be well understood what that means to the German Empire. She has, of course, enormous land frontiers, to defend which she maintains the finest army in the world. Her State railways are a magnificent aid to her from this point of view alone. She can move her soldiers, not as we have to do, for payment on private roads, to add to the profit of private persons, but at bare cost for national purposes. Where it is necessary for strategic lines to be constructed, there are they constructed. This point is dwelt upon here because, although it may at first sight appear foreign to the subject of commerce, it has a very pointed relation to commerce. It is perfectly true that the interests of defence are national interests, but so also are the interests of trade. In precisely the same way that Germany, in constructing and working her railways, has regard for defence from a national point of view, so also she has regard for her commerce from a national point of view.

The Impossibility of a Private Company Working for National Ends

Such an aim cannot possibly exist for a private railway company granted a monopoly to work one particular route or one particular district of any country. For one thing, a private company working an eastern, or a western, or other district can obviously only have regard to, and only properly survey, that particular district. It is but necessary to travel across country in the United Kingdom to realise that.

Let us recall what it is that differentiates modern trade from the trade of the past. It is the improvement of the road and the improvement of sea transport, which is, again, the improvement of a road. What do we mean by improving a road ? We mean making it easier and cheaper to get from one place to another, or to transport goods from one place to another. If, therefore, we adopt a system which prevents us making the fullest use of the engineers' work, we, in effect, erase part of the engineers' work.

That, it is to be feared, is the position that obtains in the United Kingdom as compared with Germany. Because the German trader enjoys a fuller use of his railroads—that is, enjoys cheaper freight rates than his British rival—he has a preferential advantage which means much to him. The cost of transport enters very largely into every wholesale and retail price. Fuel has to be carried, materials have to be carried, the finished articles have to be carried. Railway rates form part of every price; and when one considers how frequently a railway rate has to be paid in connection with every article we consume or use, we understand that an accumulation of large and small differences tells heavily in business. And the stimulation of trade, by favourable rates, enables profits to be made on the rates in spite of their cheapness. That is the remarkable thing about the German national railways. After giving low rates of transport to traders, the German railway administrations make a net profit of about *fifty millions sterling per annum*—a clear case of small profits and quick returns.

The Enormous Over-Capitalisation of the British Railway Companies

We noted, in considering the European railway figures, that those of the United Kingdom have not shown a satisfactory expansion in recent years. Undoubtedly that is owing to the fact that the British railway companies have found it difficult of late to raise new capital, because of the enormous extent of their existing capital indebtedness. British railway capitals now aggregate £1300 millions, a figure out of all proportion to the proper value of the undertakings, as may be gathered from the fact that the Prussian railways, which are of similar mileage, are reckoned by the Prussian Government to have a capital value of only £450 millions.

The Widespread Effect of the Coming Electrification of Railways

It is of vital importance to observe in this connection that the future of industry and of commerce is largely bound up with the organic connection between power supply and the transport system. The time is close at hand when not merely tramways and suburban railways but main line railways will be worked electrically. That will mean a revolution in something more than railway transport, great though that end is in itself. Electrification of railways means greater speed, greater convenience, absolute cleanliness, and, in the end, lower costs. If we consider it, therefore, merely in its relation to commerce, we have the highly encouraging prospect of an abundant stimulation of trade activity in every direction.

Even more important than the direct

effects of railway electrification are the indirect effects. In order to supply current to the railway system of a country as a whole, it becomes necessary to manufacture current on an exceedingly large scale. Great power-stations have to be erected, at suitable centres, for railway purposes, and a great possibility at once arises. It is to electrify not only railways but the entire industry of the country.

How the Entire Industry of the Country may be Electrified and Unified

From the great power-stations current can be supplied for every purpose which employs light or heat or mechanical power. The work of factories, the work of mines, the work of municipalities, the work of shops and warehouses, the work of private homes, can be based upon the most convenient form of energy-supply known to man. No longer, under such a system, are needed furnaces large and small, clumsily and wastefully burning coal to produce power a little bit at a time, and with it to produce dirt and inconvenience. Power is laid on like water, and as readily tapped. It becomes possible to render a manufacturing town or district as clean as a Royal park. Chimneys no longer belch out smoke, which is at once an expression of waste and a cause of hard and degrading labour. It becomes possible to do many things which could not otherwise be attempted. All sorts of domestic appliances and machinery can be utilised to change entirely the character of woman's labour, and to make it no longer true that a woman's work is never done. Processes requiring the application of heat, such as cooking, become simple and agreeable. Involved in all this is an enormous expansion of industry and of commerce.

Keeping Abreast of Science is Keeping Abreast of Industrial Progress

We see again how intimately connected are the various branches of science. They are not in watertight compartments, in which each can be regarded as cut off from the other, to be the subject of purely separate consideration. The progress of industry and commerce, and transport and society, are indissolubly connected; and when we affect one branch we set up changes in others. It is quite impossible to understand either existing trade or to have an intelligent outlook upon the trade of the future without a general grasp of scientific truth. The importance of this cannot be insisted upon too forcibly, for, if there is real danger before the British people as a race dependent on commerce, it is that they are too apt to neglect scientific attainment. We have continuously to be adapting our methods and our conceptions to the needs of our time in the light of science. It is not a matter of fighting a battle once and for all, and getting the thing done with. It is a never-ending warfare with Nature which Man has to wage; and the contest can only be carried on to the greatest advantage by keeping ourselves in the van of scientific progress.

The time has gone by when industrial and commercial operations were carried on in little, and slowly and blunderingly. We have arrived at an epoch in the world's history when the winning of supplies, the transport of supplies, the exchange of supplies, the manufacture of commodities, alike call for a high standard of training and a considerable personal equipment. We have arrived at a period when, if a man is to do anything serious in the work of the world, he must have a general elementary grounding in science as a whole, and a special grounding in the branches applicable to his work.

The Long and Studious Modern Preparation for Invention

Invention is no longer a mere seizure with a brilliant idea while shaving. That might easily be a hundred years ago, when a thousand simple ideas, such as running a vehicle on a smooth rail, or utilising a crank motion, or blowing a piston along with steam, had not yet been "discovered," or hit upon. The scientific inventions and discoveries of to-day are of another order. To make a definite improvement of value in wireless telegraphy, or to discover a new element like radium, or to produce indigo blue by chemical synthesis, or to investigate the properties of the theoretical ether of space, a man must submit himself patiently to years of preliminary education and training, *merely to bring him to the point at which he can start.* It is not possible for an untrained man to do work worth doing nowadays. The captains of industry have either to arm themselves with the weapons which science offers or to suffer ignominious defeat.

Our study of trade and the road thus raises very large and serious considerations. Transport lies at the root of commerce, and commerce and the engineer have to go hand in hand. It is a matter of national concern that they should do so. Our survey of the world's railroads has shown us that everywhere the unknown is being made the known, and that all the earth's treasures are being opened up, *for the use of the British people amongst others.* The hopes of progress are for practical purposes illimitable.

A PICTURE OF WORLD DEVELOPMENT.—THE WORLD'S RAILWAYS SINCE 1850.

COUNTRY	1850	1870	1890	1908
EUROPE:	Miles	Miles	Miles	Miles
United Kingdom	6,621	15,537	20,073	23,205
Germany	3,637	11,729	25,411	35,475
France	1,714	11,142	22,911	30,049
Russia	310	7,098	18,059	34,700
Italy	265	3,825	7,983	10,441
Austria-Hungary	954	5,947	16,490	25,763
Switzerland	15	·885	2,014	2,825
Belgium	554	1,799	2,810	2,998
Holland	110	874	1,621	2,198
Norway	—	224	970	1,604
Sweden	—	1,089	4,980	8,301
Denmark	20	470	1,217	2,113
Spain	17	3,400	6,070	9,031
Portugal	—	444	1,316	1,465
Turkey	—	392	900	1,239
Bulgaria	—	139	498	987
Roumania	—	154	1,546	1,979
Servia	—	—	335	430
Greece	—	6	280	845
Total: Europe—	14,217	65,154	135,484	195,648
ASIA:				
Russia	—	—	—	6,728
India	—	4,775	16,345	30,576
Ceylon	—	75	192	566
Straits Settlements	—	—	—	21
Japan	—	—	1,139	5,159
China	—	—	80	2,623
Total: Asia—	—	4,850	17,756	45,673
AFRICA:				
Egypt	—	742	961	1,447
Union of South Africa	—	—	2,046	7,336
Rhodesia	—	—	—	2,143
British East Africa	—	—	—	584
Mauritius	—	—	92	130
Nyassaland	—	—	—	113
Nigeria	—	—	—	268
Gold Coast	—	—	—	168
Sierra Leone	—	—	—	227
Total: Africa—	—	742	3,099	12,416
AMERICA:				
United States	9,021	52,922	166,654	232,046
Canada	66	2,617	13,256	23,658
Newfoundland	—	—	112	656
Mexico	—	215	6,037	14,845
Argentina	—	637	5,434	14,111
Brazil	—	504	6,135	11,863
Chili	—	452	1,682	3,451
Peru	—	247	933	1,470
Uruguay	—	61	953	1,371
Costa Rica	—	—	150	416
British West Indies	—	—	155	294
British Guiana	5	21	21	95
Total: America—	9,092	57,676	201,522	304,576
AUSTRALASIA:				
Australian Commonwealth	—	953	9,524	16,101
New Zealand	—	46	1,956	2,711
Total: Australasia—	—	999	11,480	18,812
GRAND TOTAL (almost complete)	23,309	129,421	369,341	577,125

LEADER AND HISTORIAN OF HIS TRIBE

Among uncivilised peoples the old man retains his power because he is the wise man, or the preserver of the traditions and customs of the tribe on which prosperity is believed to depend

THE ORIGIN OF KINGSHIP

How the Magician of Savage Races Became a Wizard Chief, and then a Royal God

SUPERSTITION AS A SOCIAL FORCE

It is not generally known that King George and Queen Mary are the descendants of a god. King George does not profess to inherit any of the qualities of the heathen deity whose name we preserve in our name for the fourth day of the week—Wednesday, or Woden's day. He does not even touch for King's Evil, as Queen Anne touched Dr. Samuel Johnson. No doubt he would say, as William of Orange said when a man flung himself at his feet praying to be healed by the Royal touch, "God give you better health and more sense." Yet ancient records enable us to trace back the English kings to the pagan days when they mightily prided themselves on the fact that they were human gods, with Woden as their not remote ancestor.

The Emperor of Japan is a man of as much common sense as King George. But he, too, is the descendant of a deity. In his case, the sun-goddess very graciously came down to earth and formed some savage tribes into a nation, and governed them, the first Mikado being her child. Every Emperor of Japan was worshipped by his people as an incarnation of the sun-goddess. Up to the middle of the nineteenth century there was one month in the year in which nobody frequented any of the Japanese temples. It was useless, because all the shrines were deserted by the gods. They were spending a month at the Court of the Mikado, and humbly waiting upon him and revering him in his divine capacity.

It is well known that the Emperors of China were the sons of heaven; and one reason why the Manchu usurpation has now ended in the foundation of a Republic is the fact that the strange new line of northern barbaric chiefs had no superstitious hold on the popular mind. The history of their conquest of the throne was much too recent for them to revive effectually the ancient tradition of the divinity of the sovereign.

This tradition has at one time or other been practically universal in monarchical governments. The early Babylonian kings, from Sargon to the fourth dynasty of Ur, claimed to be gods in their lifetime. The ancient kings of Egypt were worshipped as the son of the sun-god, and so were the Emperors of Peru. The earliest kings of Alba and Rome were little, earthly Jupiters —sons of the god of the sky and the thunder and the oak-tree. Less is known at the present about the primitive kings of Greece, but the little that is known goes to indicate that they were persons with supernatural attributes. In fact, all the Aryan races from India to Ireland were originally governed by rulers who were supposed to possess divine powers, by means of which they could fertilise the earth and alter in various ways the course of Nature. The deification of the Roman emperors, which caused such scandal among the early Christians and led to their persecution, was not an extraordinary event. On the contrary, it was only a revival of one of the commonest customs of primitive monarchy.

It is difficult for us to understand it, for the reason that our ideas of Divinity greatly differ from the ideas which the pagan races of the world still retain on the subject. They cannot rise to our conception of a Divine Power of a purely spiritual nature underlying all the shows of time and space. Some savage tribes have, it is true, a notion of a Divine All-Father, but they regard Him as a kindly human ancestor who has been exalted to the spirit world. Their idea of the universe is so narrow and childish that they cannot get beyond the idea of a ghostly magician of a benevolent nature. In short, their gods are ghostly magicians, and their magicians are living gods.

It must be remembered that every savage is, in his own opinion, endowed with tremendous powers. All that the man of

science now dreams of accomplishing, the savage has for hundreds of thousands of years calmly assumed that he achieved by means of magic. The mad wonders that happen in our genuine fairy-tales are traditions of the childhood of our race, when man lived in a world of mystery which he thought he could mould to his heart's desire by babyish rites of magic. Such was the mental atmosphere in the days when the wizard welded tribes into kingdoms.

The Secondary Place Filled by Fighting-Men in Superstitious Tribes

Before Professor J. G. Frazer completely revolutionised our ideas of the origin of the higher forms of government, it was generally assumed that brute force had prevailed in the making of the earliest nations. Undoubtedly the warrior has been a constructive force in human affairs; and in a previous part of this work we showed how much the sword had done in consolidating mankind, introducing new elements of culture among backward races, and enforcing the co-operation necessary for progress to civilisation. But in the earliest societies the fighting-man is often less potent than the magician. Not by force of arms but by the power of superstition is government maintained in the rudest of existing social groups representing primitive man.

The blackfellows of Australia, for instance, are not ruled by their best fighting-men, but by very old wizards. The social organisation is loose, and it has often been mistaken for a primitive democracy, with neither chiefs nor kings. But as a matter of fact it is a harsh and tyrannical oligarchy of old men. It is a government by elders; and the headmen undertake the task of performing magic ceremonies for the multiplication of various animals and plants on which the clans live. In short, most of the headmen are magicians who are assumed to provide the people with food. Others have to make the rainfall and render similar services to the community.

How Men Careless of Bodily Harm Succumb to Ghostly Fears

They are public wizards. Their most important function consists in taking care of the sacred storehouse; and this is usually a cleft in the rocks or a hole in the ground, in which are kept the holy stones and sticks of the tribe. With these stones and sticks the souls of all the people, living or dead, are bound up. The wizard calls the tribesmen together for initiation ceremonies and public discussions. In fact, he is a chief in all but name, and if he aspires to great influence he must be a skilful conjurer. For some tribes in South-Eastern Australia have reduced the test of all candidates to headmanship to a simple matter. The greatest headman, according to their way of thinking, is found in the man who can produce the largest number and variety of things from his inside. Messrs. Maskelyne and Devant would easily defeat Lord Roberts and Lord Kitchener in a contest for the chieftaincy of any of the lower savage tribes.

This will at once be understood by putting ourselves at the point of view of the savage. He does not fear any bodily hurt. Many savage races are continually engaged in warfare. Every expansion of population leads to quarrels about territory, which end at last in the ordeal of battle. As a rule it is the young fighting-men who are most eager to resort to the use of force; and if there were no means of keeping them in check, they would rebel against the authority of the old men.

The Subservience of the Man who Cannot Call His Soul His Own

It is here that the influence of the tribal wizards tells. Taking a cunning advantage of the wildly superstitious nature of the savage, they rule him by ghostly terrors and magic customs until he cannot, literally speaking, call his soul his own. They can raise up ghosts to haunt him, and cast awful spells upon him, and even make him waste away like a wax image before a fire. And all this can be done secretly, so that the punishment falls in a sudden and mysterious manner without any warning. What is the power of a man who can throw a spear or use an axe a little quicker than his fellows, compared to the ghostly abilities of a magician? When the matter is looked at in this light, the marvel is not that kingship largely arose out of wizardry, but that any warrior chief of a later date ever succeeded in subordinating the witch-doctors of the tribe.

In New Guinea the level of culture is higher than it is among the blackfellows of Australia, but many of the races are still unorganised into chieftainships. Now and then, however, some renowned wizard manages to get into the position of a temporary king. Wars, marriages, deaths, raids, and fishing and hunting expeditions are all under the dominion of the magician. For nothing would prosper unless he had been consulted about it, and given offerings to perform the rites that bring success. He is the master of life and death, and so he is feared and obeyed in everything he

demands in a way that no man relying on mere force could command.

One man of the Taoripi tribe of British New Guinea has been made a chief because he can rule the sea, calming it or rousing it to fury at his pleasure. Another owes his power to his skill in making the rain fall and the sun shine, and compelling the trees to bear fruit. The present chief of Wedau is also famous as a rain-maker and a wind-controller. In this stage of society the road to power is open to all the talents. Everybody practises magic, and believes in it, but some men have more self-confidence than others. Perhaps they are more intelligent and less impressionable than the majority of their fellows; anyway, they grow bold enough to lay claim to the possession of supernatural powers of an unusual nature, and succeed in convincing the people that they possess them.

Such seems to be the method by which some sort of central authority is obtained by an able and cunning man among the lowest races now known to us. When ancestor-worship develops into something like religion, the wizard chief is often able to hand on his authority to one of his sons or male relatives. In some South Sea Islands, for example, the power of the chiefs rests on the belief in their spiritual and magical genius, and this genius is derived from the spirits of ghosts with whom they have intercourse. In any case of difficulty they are able to bring down on their enemies the influence of the spirits. If a chief imposes even an unjust fine, his people pay it, because they are afraid that if they anger him he will bring a plague upon them.

In one of the New Hebrides there is a nobility which, like most primitive aristocracies, is founded upon wealth. But the wealth is used in a very curious way. Those persons who have been able to afford it have sacrificed a thousand little pigs to the souls of their ancestors. Nobody dares in any way to resist a man who has carried out this sacrifice. For in him is supposed to dwell all the souls of the ancient chiefs and all the spirits who preside over the fluctuating fortunes of the tribe.

The spiritualistic medium of the modern era, who asserts that he is on terms of familiar intercourse with Julius Cæsar and Bacon and the rest of the mighty dead, possesses many of the advantages of a New Hebrides nobleman, but our incredulity prevents him from making the best of his very aristocratic connections. Had he lived two thousand years ago he might, if circumstances had favoured him, have become the king of his tribe. Had he then possessed some military talent in addition to his spiritualistic ability, he could have gone forth to conquest and founded a nation.

As a political instrument, the apparatus of a magician is more useful than the axe of a warrior. A soldier chief of primitive or savage race cannot always make sure that his descendants will inherit his powers. They may be only young men, and not so strong of body and full of courage as he was; and their claim to the leadership may be disputed by some older man with more experience and fame in war. In the absence of any superstitious reverence for the offspring of a self-made leader, a nation would probably be destroyed by

WODEN, THE MYTHOLOGICAL ANCESTOR OF OUR ENGLISH KINGS

"Ancient records enable us to trace back the English kings to the pagan days when they mightily prided themselves on the fact that they were human gods, with Woden as their not remote ancestor."

tribal and personal jealousies and ambitions, long before its internal industrial development so consolidated it that it could survive recurring periods of anarchy. Where, however, somewhat of the prestige of magical power still attaches to the kingly office, kingship can descend from father to son.

Where Chieftainship Depends on the Inheritance of Magical Powers

In Northern New Hebrides, for instance, a son does not directly inherit the chieftainship; but as he knows his father's magical incantations, and possesses his sorcery stones and other magic instruments, he is usually able to succeed to the office. Moreover, the son of a wizard chief is often regarded by savage people as an incarnation of the father. As soon as the father dies, his spirit enters the body of the son. What becomes of the soul of the son in this case is a matter of which we have no knowledge. The superstition, however, is very useful in maintaining the continuity of a central power of government and preventing usurpation and disorder.

As we have seen, the Mikados of Japan are successive incarnations of the sun-goddess. So when a soldier usurped the kingly power, during the wild feudal wars which only closed in the lifetime of the present Emperor, the sacred person of the monarch had to be respected.

The victorious usurpers only maintained their power over the popular mind by imprisoning the Mikado, and pretending that he was so holy that he could not be seen, and thus could only act through them. They professed to be only humble servants of the Royal god—in somewhat the same way as the usurpers of power in Tibet shielded their "eternal and heavenly father" from the public gaze—and they carried on the government ostensibly as his merely human servitors.

The Difficulties of Usurpation in Lands where Superstition Reinforces Kingship

The way was thus left open, through all the disorders and civil wars of Japan, for the Mikado to assume full and direct authority when the chiefs of the clans awoke to the fact that their country was endangered by their jarring ambitions.

Usurpation is always difficult in a primitive monarchy. It means, looking at the affair from a primitive point of view, no rain, no crops, cattle sickness, and a plague among the people. All the spirits of the dead chiefs conspire to punish the nation, and no ordinary magician can prevail against their combined efforts. Thus when, in ancient Ireland, Carbery Kinncat usurped the throne, the chroniclers relate that only one grain grew on every cornstalk, and no cow gave any milk. In Scotland, the stone on which a king sat to be crowned showed if he were not of the Royal race. It is now used in Westminster Abbey at the Coronation of the ruler of the British Empire, but it has apparently lost its power of speech—though some Jacobites may have another theory on the matter!

The regalia of royalty may very likely be derived from the instruments of magic that the wizard chiefs of old bequeathed to their descendants. We have already seen that the symbols of a great sorcerer are still very effective in enabling his son to assume authority over a savage tribe. In the Indian Archipelago the regalia are regarded as the fount of regal dignity. In southern Celebes the Royal authority is even supposed to be embodied in some mysterious fashion in the symbols of kingship. The princes owe all the power they exercise, and all the respect they enjoy, to their possession of these precious objects. In short, as Professor J. G. Frazer remarks, the regalia reign, and the rulers are merely their representatives. So whoever happens to possess the regalia is regarded by the people as their lawful king.

People Who Regard the Royal Regalia as a Wonder-working Talisman

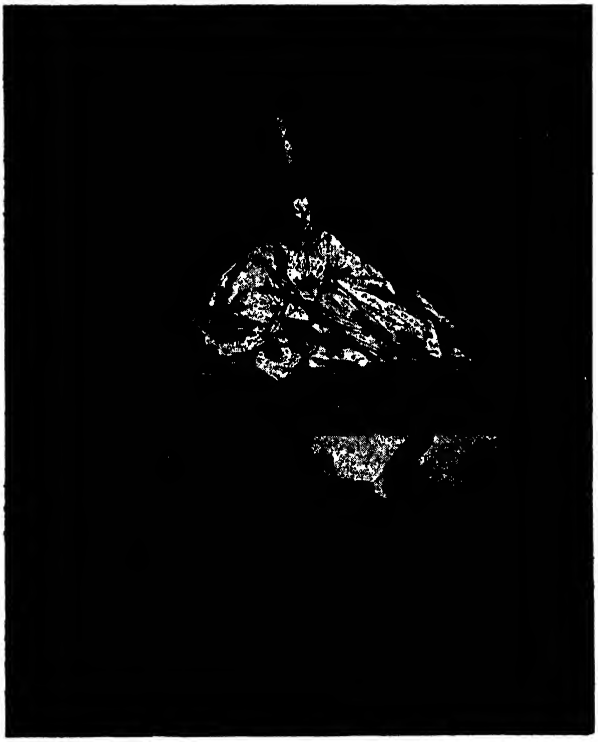
If a deposed monarch contrives to keep the sacred insignia, his former subjects remain loyal to him in their hearts. His successor is merely a usurper, and obeyed only in so far as he can exact obedience by force. So the first aim of rebels in any insurrection is to seize the regalia; and if they are successful the authority of the sovereign is gone. Temples are built for the regalia to dwell in, just as if they were living creatures, and furniture, weapons, and even land are assigned to them. In times of disaster they are brought forth as instruments of magic for the purpose of staying the evil. Sometimes the regalia consist, like the instruments of the savage magician, of stones and pieces of wood and curious dried fruit. When a missionary asked to see some of these objects, the native guardian replied that if he were to open the bark-cloth in which they were wrapped there would be an earthquake!

Thus in the Malay region the regalia are still merely wonder-working talismans which the modern king seems to have inherited from the ancient magician. So we may conjecture that in other parts of the world the

emblems of royalty may have had a similar origin. In ancient Egypt, for instance, the two Royal crowns, one white and one red, were supposed to be endowed with magical qualities. They were divinities, being, like Pharaoh, embodiments of the sun-god. Sometimes the guardianship of the magician instruments is a source of great inconvenience to the wizard chief.

A few years ago the headman of Etatin, on the Cross River, in Southern Nigeria, was an old man whom the people had compelled to take office in order that he should look after the fetishes or ju-jus, and work magic for the benefit of the community. In accordance with an ancient custom, which is binding on the head chief, he was never allowed to leave the enclosure in which his house stood. He gave the following account of himself to an English official who paid him a visit:

"I have been shut up ten years, but, being an old man, I don't miss my freedom. I am the oldest man of the town, and they keep me here to look after the ju-jus, and to conduct the rites celebrated when women are about to give birth to children, and other ceremonies of the same kind. By the observance and performance of these ceremonies I bring game to the hunter, cause the yam crop to be good, bring fish to the fisherman, and make rain to fall. So they bring me meat, yams, fish, and other offerings. If I were to go outside this compound, I should fall down dead on returning to my hut."



THE DIVINITY OF KINGS—THE OBEISANCE OF THE NOBLES TO THE MIKADO OF JAPAN

We can all remember the superstition about "Queen's weather" which attached to Queen Victoria. Whenever she appeared at a public function the sun was sure to shine. The Kings of Mexico took an oath when they were crowned that they would make the sun shine, and the clouds give rain, and the rivers flow, and the earth bring forth abundantly. Such were, indeed, the chief duties of a primitive king. The Chinese Emperor has always held himself personally responsible for very severe droughts, and many self-condemnatory edicts in this matter have appeared in the Peking Gazette. The rulers of Korea and Tonquin were also blamed for bad harvests, typhoons, and epidemics. When things were very bad, the Tonquin king changed his name. If that did not remedy matters, he transferred the kingship to his brother or son, or some near kinsman.

The office of a king certainly had some amazing disadvantages in primitive days. A magician who could not work magic at the proper time was often in danger of losing his life. The fact that his people were too profoundly superstitious to dream of questioning his powers only increased his peril in adverse circumstances. A succession of bad harvests never showed that the Royal art of rain-making was an imposture. It only convinced the people either that their king was spiteful and bent on doing harm to his subjects, or that the spirits were punishing the people because they did not get a better king.

The Edonians of Greece put their king, Lycurgus, to death during a very bad harvest. The Burgundians usually deposed their rulers whenever the crops failed; and in a famine the Swedes sacrificed King Comalde to their gods. The Scythians put their king in bonds when food was scarce,

and did not release him until he relented and worked the magic that made the people happy. More chiefs and kings throughout the world have fallen because rain did not fall at the proper time than because of any sound political reason. There are, indeed, cases where a change from monarchical government to republicanism has been brought about entirely by superstition. On Savage Island formerly reigned a line of wizard kings who were supposed to make the food grow. But a succession of bad seasons set in, with the result that the kings were killed one after another, till at last no one would undertake the office of kingship. So the monarchy came to an end.

The Dangerous Honour of a Kingship Depending on Health

It is still not uncommon to find among savage and barbaric races another strange peril attaching to the kingly office. The magician first climbs to chieftainship, and then acquires divine qualities. To the mind of a savage, the difference between a powerful sorcerer and a god is not clear. His gods are often merely hidden magicians. So he is ready to regard his kings as human gods, and to obey them with extraordinary humility. A god, however, must not be subject to human maladies. At the present day many petty kings of Africa are bound in honour to commit suicide as soon as they feel themselves to be ill. So much depends upon the Royal magicians being in a fit state to exercise their supernatural powers that their health becomes a matter of supreme national importance. Strange ordeals have been employed to test the continued strength of the king. There have been many monarchies in which at stated periods the ruler had to engage in a deadly combat with any man who cared to fight for the crown. The earliest kings of the Roman people, for instance, had to enter once a year a sacred grove, and fight against any rival. And in India, as late as 1743, the King of Calicut had either to cut his throat in public at the end of a reign of twelve years, or to stand on a ridge, at some distance from the temple, and fight continually for twenty-eight days against the best of his youngest swordsmen.

How the Ordeals on which Kingship Depended Have Been Evaded

Generally speaking, the primitive kings of the world were able to surmount the difficulties which they created for themselves by their pretension to magical and divine powers. Men of masterful character merely used at last the magician's wand to clear the way to the throne. Having won to it they maintained themselves by the power of the sword, and reduced the annual fight or other periodical ordeal to the empty form it often assumed in historic times. The kings of Rome, for example, avoided the sacred grove, and appointed some criminal to be the annual king of the wood, and the custom became a yearly conflict between malefactors and outcasts. And the King of Calicut, when the twelfth year of his reign arrived, took his accustomed station on the ridge, but surrounded himself with forty thousand fighting-men. No swordsman ever cut his way through the long barrier of spears.

The responsibility for the control of the seasons and the supply of food was evaded, in many cases, by delegating the functions of looking after the weather and the health and prosperity of the people to a class of subordinate magicians, like those that Moses encountered at the Court of Pharaoh. Moreover, in most of the earliest civilisations the practices of totemism and fetishism developed into a system of idolatry. The animals which the primitive magician of the tribe once had to make to flourish were raised to the rank of gods, and left to look after themelves. If they did not attend to the wants of the people, in spite of the prayers and sacrifices offered up to them in seasons of drought or plague, their images were taken from the temple and beaten and dishonoured.

The Rise of Royal Despots Beneficial Compared with Savage Wizardry

All this saved the persons of the kings, and enabled them to kick away the ladder by which they had climbed to the throne. Giving up the use of the black art, without, however, relinquishing their "divine rights," they became priestly despots, and, as such, they emerge into the light of history. The general result of the evolution of the savage wizard into a Royal despot was to place the supreme power in the hands of men of the keenest intelligence and the most unscrupulous character. The change from the primitive oligarchy of old men—all of them magicians—to a monarchy in which the rule of a single ruler prevailed was, on the whole, beneficial. As Professor J. G. Frazer remarks, no human being is so hide-bound by custom and tradition as the apparently democratic savage. He is a slave, not, indeed, to a visible master, but to the past—to the spirits of his ancestors, who guide his steps from birth to death, and govern him with a rod of iron. In no other state of society is progress so slow and

difficult. Scarcely any scope is afforded for men of superior talent to change old customs for the better.

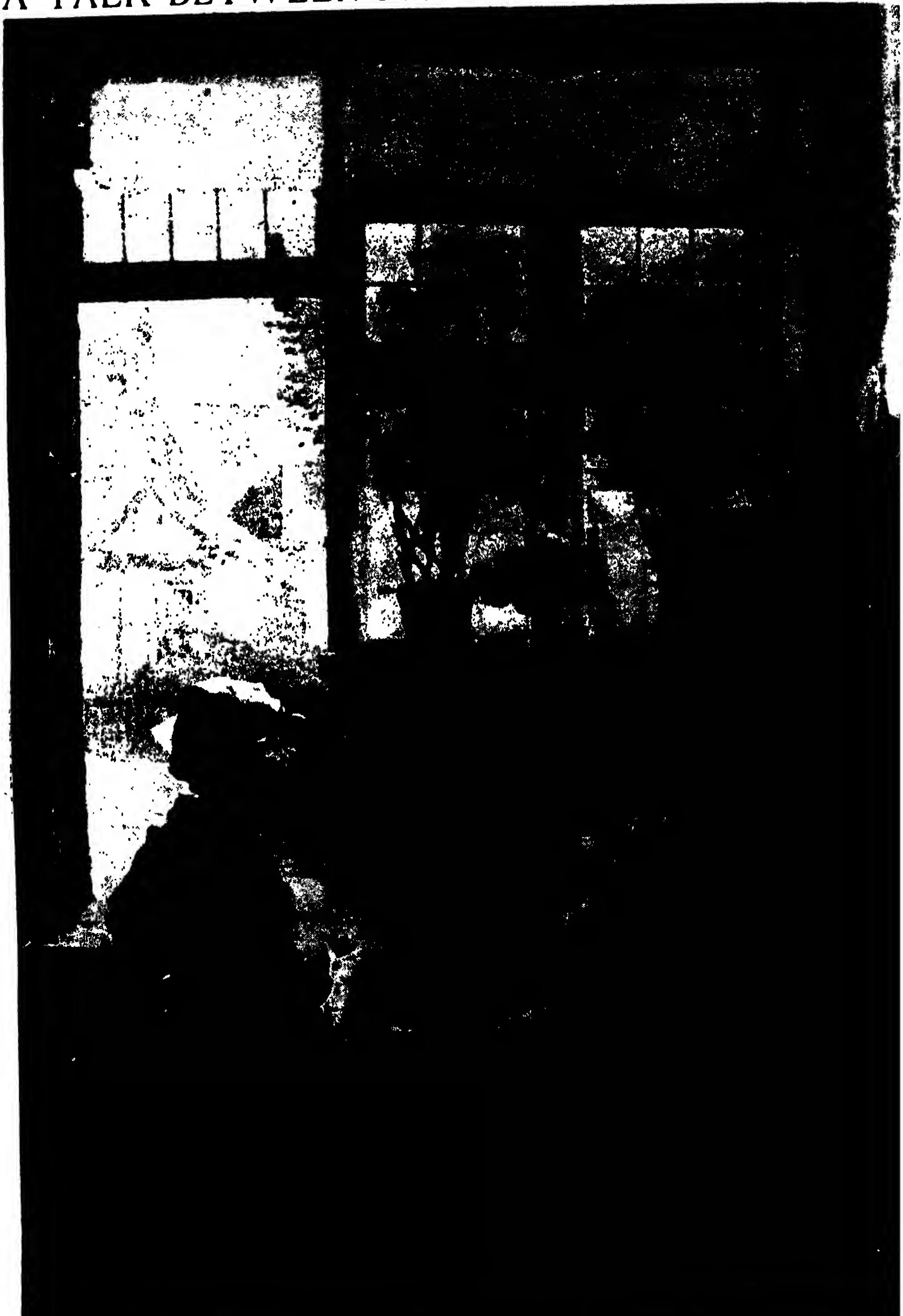
From this low and stagnant condition of affairs, the cunning magician uplifted his duller-minded fellow-men, by playing on their superstitious fears. The rise of one man to supreme power enabled him to carry through in a single lifetime changes which many generations might not previously have sufficed to effect. It is not an accident that all the first great strides towards civilisation were made under despotic and theocratic governments, where the supreme ruler received the servile allegiance of his subjects in the double character of a king and a god. At this early epoch the despot often was a liberator. Under the most grinding of early tyrannies there was more liberty of mind and soul than under the apparent freedom of savage life, where the lot of the individual from cradle to grave was, and is, cast in the iron mould of hereditary custom. Here is the conclusion formed on the matter by Professor J. G. Frazer, who has done more than any man since Herbert Spencer to illuminate the course of the social evolution of mankind:

"So far as the public profession of magic has been one of the roads by which the ablest men have passed to supreme power, it has contributed to emancipate mankind from the thraldom of tradition, and to elevate them to a larger, freer life, with a broader outlook on the world. This is no small service rendered to humanity. And when we remember further that in another direction magic has paved the way for science, we are forced to admit that, if the black art has done much evil, it has also been the source of much good; that if it is the child of error, it has yet been the mother of freedom and truth."

MAGIC BEHIND THE THRONE—AARON AND THE ROYAL MAGICIANS AT THE COURT OF PHARAOH

Of course other factors, beside superstition and wizardry, concurred in the evolution of the earliest forms of government. There was, for instance, the terrible ordeal of battle, which acted as a selective agency between neighbouring but quarrelsome groups. If superstition weakened a people instead of giving it more cohesion, that people became broken up in the next period of fierce warfare. Thus the power of wizardry was, to some extent, checked and directed by interaction with other social forces.

A TALK BETWEEN MOTHER AND DAUGHTER



The evolution from girlhood to womanhood raises many questions of transcendent importance be talked over, as here, with a mother.

From a photograph by Neurdein Frères of the painting entitled "A Difficult Question," by G. Haehl, in the Luxembourg Gallery, Paris.

EDUCATION IN PARENTHOOD

The Drift of Blind Ignorance in the Young Allowed by Prudishness and Folly

THINGS THAT ARE PURE TO THE PURE

If education be "the provision of an environment," the function of which is "to prepare for complete living," it is evident that educators must decide what they mean by complete living, or their preparation may fall short in some essential particular. If the Eugenist consults educators to learn what it is that they aim at, he finds complete disagreement among themselves in every particular except that with which he is most concerned. A dominant school of educators, whose influence tells upon our education alike of the young peer and the young ploughboy, tries to turn all boys into classical scholars. Another cares mainly for athletic success. The most expensive education of girls aims partly at the higher mathematics and partly at the higher hockey. More recent theories aim at commercial success, or at technical efficiency. But, amid this welter of conflicting aims, all educators, with the rarest individual exceptions, despised by the rest, agree in excluding the function of parenthood from their idea of complete living. They will prepare the boy and the girl for anything but that; but that, and whatever leads up to it, they will ignore, not by oversight, still less by insight, but by the fatal lack of sight which afflicts those who "won't see."

This is not a new fact in our country, nor is it newly drawn attention to here. On the contrary, the greatest educational reformer of the nineteenth century, Herbert Spencer, in his work on "Education," published in 1861, made the very protest which we here repeat with even greater necessity, more than half a century later. He opened his famous chapter on Moral Education by pointing out, in a long passage which the reader should consult for himself, that while educators dispute over the constituents of the curriculum, and the relative importance of classics, mathematics, and so forth, the greatest defect in our educational curriculum is overlooked by everyone. We act as if parenthood were unimportant, or required no preparation, or would only fall to the lot of the very few; whereas it is supremely important, is the most difficult task in life, and falls to the lot of very many.

If this protest of Herbert Spencer's were needed in 1861, how much more is it needed in 1912? Not only have we done nothing to remedy the defect of which he complained, but we are making many mistakes in the opposite direction; the rate of infant mortality is still terribly high, and the birth-rate is a mere fraction of what it was when he wrote, and is lowest in the "best" and longest educated classes of the community. As regards boys, no substantial change has been made in the last half-century. As regards girls, Spencer's own influence has had results which he would be the first to deplore. His work freed girls from the artificial confinement, useless, eye-destroying, lung-cramping employment, and false standards of propriety which marked their education in his time; and now the pendulum has swung over to the other extreme, so that the great idea of the "best" modern girls' schools is to bring the girls up as if they were boys, to demonstrate their equality, if not their identity, with boys in intellect and muscle, and to turn their bodily development and their ideals away from marriage and motherhood.

Against all such tendencies the Eugenist is bound to set his face. We have traced the nurture of a new generation from before the cradle until the great change called puberty, initiating adolescence and the possibility of parenthood. But, from

the eugenic standpoint, this is, in part, the object of all our care. We want fine individuals for their own sake, but we also want them as parents; and we want nothing less than to devote all possible skill and care to the nurture of young individuals, only to discover that they renounce parenthood, and leave that supreme function to be discharged by others upon whose own development less labour has been expended.

The Parental Outlook Needed by all From Early Adolescence

In short, Eugenists are bound to demand the formal, wholehearted, and practical recognition of the place of parenthood in the ideal of "complete living," and to regard this, and this alone, as the real business of the "finishing school," for youth of either sex. Not all children will become parents. But all, whether personally or in their business as citizens of the State, will at least become foster-parents, and will be none the worse, and all the better, for having had the parental outlook, the parental idea, instilled into their minds in early adolescence. And further, as will be clear when the theory of eugenic education, or education for parenthood, is fully understood, one of its most valuable results may be to interfere with marriage and parenthood on the part of those who may learn that this abstention is a duty they owe to the future because of the likelihood of passing on some taint, which may or may not be apparent in themselves personally, but which is present in the stock to which they belong.

The importance of instruction, especially in the details of motherhood, is now coming to be generally recognised. "Schools for mothers" are doing valuable work. We all realise that maternal ignorance is an important factor—indeed, the most important—in the causation of infant mortality. The writer has worked for the instruction of motherhood for nearly a decade, and believes in its importance more than ever, but that is *not* what he means by eugenic education. Instruction is not education, though it is a necessary instrument of education.

The Choice of the Fathers of the Future the Most Important Function of Motherhood

If the girl has been persuaded into marrying a young drunkard in the fine but fruitless hope of "saving" him, it may well be, in many cases, that it were better for her and the future that her child should die than that it should live. Education for parenthood is concerned not merely with the care of the child, but with the choice of the child's father; and, so far as girls are concerned, it will subtly but surely direct them towards discharging what is perhaps the first and most important function of motherhood—choosing the fathers of the future, selecting the worth, and rejecting the unworth, that are proposed for half of the composition of future mankind.

Let us now look more closely into the problem we are trying to solve. It has a preliminary stage which is fortunately not difficult, but which must be properly attended to if subsequent stages are to be feasible at all. Long before puberty, the interest and curiosity of children are aroused as to the great mystery of motherhood. Observers assure us that this question is more difficult for urban children, especially, at the present day. Those who live in the country, and are familiar with animals, come naturally to discover the wonderful fact that young creatures are cared for within their mother's body before they are fit to be exposed to the world for themselves. But if and when children ask this question, regarding their baby brothers or sisters, the unanimous opinion of those who have first-hand knowledge of this subject is that they should be told the simple and beautiful truth, simply and naturally. In this spirit they will receive and accept it.

The Wisdom of Speaking the Truth at all Times to Children

Here the writer is following the experience of the many thoughtful women who have lately come into the eugenic movement, and from whom he has gratefully learnt. They report that children should not be lied to, that the right moment to tell a child is when the child asks, and that no difficulties arise if this exceedingly simple principle be followed—tell a child the truth when it asks a question. This, of course, is not "education for parenthood," and what is here meant by that phrase would be outrageously premature at any time before puberty, and may even be premature for a considerable period after it, but the future problem will not be solved unless parents have done their duty in this respect first.

Parents, nurses, and others who are liable to be faced with the questions of childhood on such matters ought to be aware that their duty is to answer the simple truth, no more and no less. Many years—a decade or more—may pass before any question of the meaning of fatherhood

arises; but as for the essential nature of motherhood, the experienced tell us that what strikes us as difficult to tell, and what is for us bound about with all manner of associations that embarrass us, is received by the child in a perfectly matter-of-fact and comfortable way, according to the truth that "to the pure all things are pure."

Those responsible should undoubtedly be prepared to give some timely warning of the phenomena of puberty to young people of either sex, and may thus obviate the utmost shock and alarm such as unprepared children often suffer from. But this point and the last are preliminaries for the all-important matter of eugenic education, which we are now about to consider.

The False Standards that Make Men Shirk the Problems of Adolescence

The reason why the problem has been shirked is quite obvious. It is not that we do not see its importance; it is not, in many cases, that we do not care; it is that the problem is so difficult. Two fathers who have consulted the writer on this matter have recounted the same experience. They decided that the time had come to tell their boys something. They thought a quiet walk would be a convenient occasion. They took the walk—and came home with the work undone. When the moment came, their courage failed them. Other fathers, not dissimilarly, have lost courage at the last moment, and have handed the task over to their wives. All this is a consequence of our false standards in these matters—it is part of what the writer has discussed elsewhere as "the price of prudery." Prudery is not modesty, and is a very bad substitute for modesty. A father who could not speak to his own son of things that will vitally concern his future may be quite prepared to laugh at very dubious jokes in the club smoking-room, or to tell them himself. But there the difficulty lies, and it must be overcome.

The Mistake of Throwing the Burden of Plain Talks on Teachers

Undoubtedly the tendency among parents when challenged on this matter, and especially among parents whose children are at a boarding-school, is to throw the burden upon the teachers. They say this is the business of the teachers, and they cannot be expected to discharge it themselves. But there is another side to this assertion; and the writer, who has lectured to teachers on this subject for many years past, is entirely on their side in the matter. Whether we deal with boarding-schools or board-schools, with boys or with girls, the teachers say the same thing. They care about this matter. The good type of teacher, of either sex, and there are many such, wants to be useful to the boy and the girl in this vastly important matter. But the experience of the bravest is that serious trouble awaits them unless they get definite leave from the parents, and that this leave is often not forthcoming. They add, also, that unless the soil has been rightly prepared in the home, their chance of usefully sowing the good seed at school is a very small one.

And, further, by far the greater number of children in this country leave the care of the teacher just when they are beginning to approach the age at which education for parenthood should be begun. This is really the business of adolescence. It can only effectively be discharged when the nation has discovered and recovered its adolescence on the lines laid down in the preceding chapter of this section; and, indeed, the need of this education is, from the eugenic point of view, the most cogent of all the many cogent reasons why we must at once undertake the care of adolescence which we now allow to run wild in the great majority of cases.

The False Views and Wrong Conceptions That Come to the Young by Chance

Let us, then, not lightly assume that this problem of education for parenthood can be solved by the teacher alone, nor at all under existing conditions; and let us look at the fashion in which it can and must be solved. Young people learn things, in any case. Those who are a little older will teach them. The boy may learn from the groom, the girl from the housemaid; there is plenty of "literature" at their disposal, and the chances are high that none of these sources of information is without taint. The new powers and interests that dawn in adolescence are represented as more than half shameful, as existing for the advantage of the individual, as involving no duty to the future. The early associations of these matters in the young mind are therefore shameful, illicit, anything but eugenic.

The only counter-influence that most of them are likely to meet is that of teaching, probably clerical, which is based upon the old theories of asceticism. Such teaching is essentially repressive and negative. It condemns the new developments of the young life as animal or bestial, as requiring nothing but contempt and subjection, as opposed at all points to the interests of the higher nature. This teaching is hard, and

the few who respond to it may suffer terribly by reason of their failure to follow it completely. But the many will instinctively reject it, feeling that there must be something false in the teaching which thus blasphemes the natural, and casts a sort of slur upon all mothers. The hour has passed for ever when youth will be persuaded that the ideal life is celibate, and that fatherhood and motherhood involve a fall from human perfection.

The Disastrous Trade that Subsists on Secret But Needless Fears

An alternative to such teaching is furnished by the advertisers whose method is to terrify young men regarding these matters, describing what is normal as symptomatic of alarming disease, and then selling the abominable compounds which will ensure further attention to their advertisements on the part of their victims. The law should step in with a strong hand and expunge all advertisements that thus seek to develop and exploit sexual hypochondria—a great evil of our day, and one which leads to much misery, insanity, and suicide.

But the young person who has been properly educated need fear neither the low print nor the evil communications of the low mind that knows all the nastiness, and can see none of the beauty, of these matters; and reads the advertisements of this class with unconcerned contempt. How is such a consummation to be attained?

In the writer's judgment, four sets of persons are jointly responsible for the present state of affairs, and only the sincere and generous co-operation of all four can do what we desire. They are the parents, the teachers, the clergy, and the doctors. None of these can perform the task alone, and each of the four has special opportunities which are not open to the others. Unfortunately, these four sets of people are not always in sympathy on other matters, but if they are to succeed here there must be no jealousy between them.

A Need for Co-operation Between Parents, Teachers, Clergy, and Doctors

The first requirement is for a series of conferences and discussions, to which representatives of all four should contribute, that we may learn what is practicable, and what should be the special duty of each.

The foundations must always be laid by the parent, first, in answering the questions of childhood honestly; and, second, in suitably warning children as to the phenomena of puberty. Parents who are possessed of the eugenic idea will do more—more on their own account, besides their co-operation with others. They will maintain a home atmosphere in which the idea of parenthood is honoured, and in which marriage is thought and spoken of as involving duties to the future as well as to the present. Exceptional parents may, of course, do far more. The eugenic literature exists which may aid them in their task.

Thus, in the writer's judgment, many parents and others are handicapped in this matter by the mere lack of a suitable vocabulary. We may find it hard to talk about reproduction; but what is the need, when the word "parenthood" is available? Similarly, the sacred character of expectant motherhood may be named, to adolescents of both sexes, when we might shrink from speaking of pregnancy. And, lastly, the writer strongly urges the substitution of the term "racial instinct," for what is usually called the "sexual instinct." To call it the racial instinct is to suggest that it exists not for self but for the race, and is to be regarded as a sacred trust for that end.

The Best Method of Teaching the Scientific Facts of Parenthood

This is better and truer teaching than that which calls this instinct animal and evil, to be despised, and, if possible, destroyed; and the name suggested not only makes the thing more easily nameable, but lays the emphasis on precisely that aspect of it, *its purpose*, which is utterly forgotten by the instructors from whom youth too often learns at present.

If the foundations are laid by the parent, the teacher's task is not an impossible one. Probably the teacher's chief duty, under ideal conditions, is to link on the teaching of such subjects as botany and hygiene to the eugenic idea. Botany teaches, quite impersonally, the most important truths regarding the nature of reproduction, and the meaning of heredity. The teacher who is concerned with this delightful subject need make no special effort to point the moral; youth will be quite able to do that for itself. But there can be no question as to the utility of botany for giving a sound appreciation, especially of the meaning of heredity and the universality of its application. Similarly, as regards the teaching of hygiene and elementary physiology, the wise teacher, having the eugenic idea, and the probable destiny of the pupil in his or her head, will contrive subtly to instil the idea of personal and physical responsibility, through parenthood, not only for oneself, but also for the future. Such teaching will

be not only scientific, but also moral; and its refrain will be, "Ye are the temple of the Holy Ghost." In more literal and modern language, the adolescent is the temple, the bearer, the host, the trustee of the life of this world to come; his or her interests and powers exist not only for self but for the future, and must be looked upon as a sacred charge. So far, perhaps, upon prepared soil, may the wise teacher go.

In the future, when we no longer call in the doctor to cure us when we are ill, but employ him, personally and nationally, to keep us well, and guide us with his special knowledge in the principles of right living, the trusted doctor of the family will play his part in the great business of eugenic education. The boy who is anxious about himself, with the cruel assistance of the advertisers already referred to, will be able to learn, from a qualified and trustworthy source, that he is anxious without cause, and that if he has cause the only safe, proper, and competent person to consult is his doctor.

The Duty of the Church Towards Education for Parenthood

Lastly, there is the clergyman, or minister. Most certainly this is his business, and, indeed, the forces of religion have always taken a special interest in sexual morals in all times and places. It has already been hinted that much religious teaching on this subject has been of the wrong kind, but there are many signs to show that a new era is dawning, and that, in the near future, the Churches will take their part in the great work of education for parenthood, which so evidently concerns them. Here the writer cannot modify words which he has used elsewhere, and which may be used again.

The faithful assiduity, the variety of method, the earnestness, the perseverance with which in the past the mysteries of religion were instilled into the young—these must be rivalled and surpassed in educating for parenthood, which will be an essential part of the religious education of the future. No less definitely than the celestial religions appeal to permanent and valuable constituents of human nature, this terrestrial religion, and the education for it, appeal to powerful, almost ineradicable, elements of our being. The natural man and the natural woman are Eugenists at heart. Each of them prefers, in members of the opposite sex, youth and maturity rather than senility; beauty (which has a high degree of correlation with health) rather than ugliness; straightness and efficiency of limbs and feature rather than deformity; optimism rather than pessimism; intelligence, good temper, sympathy, rather than their opposites. There is, indeed, speaking in popular language, a eugenic sense; and the business of those who undertake the great task of education for parenthood is to educate—that is, to lead forth and develop—this sense, and, in the first place, to oppose and, if possible, destroy all those agencies, chiefly servants of Mammon, by which the growth of this most precious element of our nature is vitiated or arrested.

The Necessity for Always Suggesting a High Ideal of Marriage

But we must be very heedful of our speech. If we are to call ourselves Eugenists, race-regenerators, imperialists, or patriots, we must beware of saying, in the hearing of our juniors, that "So-and-So has made a good marriage," when we are palpably referring to factors which cannot possibly determine, nor ever did, nor ever will, the goodness or badness of any marriage. We cannot regenerate the race, nor even save our civilisation, if we are to talk—nay, worse, if we are to act—in this way within the hearing and sight of youth.

Many a sermon might be preached from this text, none the less considering that, so far as the heart of the Empire is concerned, the standard of ostentation and luxury has risen even within the memory of the young. It would need many chapters psychological and physiological, to demonstrate in how many ways, obvious and obscure, luxury is anti-eugenic, as, indeed, the pages of history, even without analysis, would go far to prove.

Our Ideal of Marriage Should Include the Abjuring of False Luxury

Here it is impossible to do more than urge that, if our education for parenthood is to comprise example as well as precept—if, indeed, it is to be worth a straw in its actual effect upon the conduct of the young generation—it must comprise a campaign against luxury in every shape and form. This is not to advocate the so-called "simple life" or the "return to Nature," as those terms are commonly understood. We can no more "return to Nature," in that sense, than maturity can return to the womb; but it is possible to accept civilisation, use the telephone, take a daily bath, enjoy the most complex orchestral music, read books, refrain from casual expectoration, and do many other things of which we should find no sign if we "returned to Nature," and yet preserve,

in personal habits of diet and sleep, and exercise and thought and desire, a simplicity and rationality which all these "modern improvements" may be made to serve.

And so far as precept is concerned, we may note, for our instruction and for that of youth, that no race or civilisation hitherto has been able to survive luxury. "Nothing fails like success," as we may state it; and the simple and efficient cause of this failure is the failure of the birth-rate. That failure has many causes, and their analysis is a great and lengthy theme, simple only to those who have given it no thought; but if we know the fact, the explanation is of no practical importance. Our duty is plain: for ourselves and those whom we can influence we will abjure indolence and ostentation and indulgence in all their forms.

The Noble and Exquisite Part Played by Love in Marriage

It follows that, when our young people want to marry for love, the foremost question in our minds will always be, Is it really love? If it be that noble and exquisite thing, if the desired partner be such a one as can evoke it in its lovely entirety, then, in the name of heaven and earth, let us beware lest we dare to regard any other question, least of all Mammon's, as of equal, if indeed of any, importance. It is, of course, impossible to compress into the space now available a whole treatise, or even a compendium, of answers to criticisms, but at least the foregoing passages may indicate the answer to a criticism which reaches the Eugenist, in public discussion and private correspondence, perhaps oftener than any other—the criticism that "love laughs at locksmiths," or (in a slightly different form) that the Eugenist is proposing to ignore or even to outrage one of the most beautiful and precious attributes and possibilities of human nature. The Eugenist who proposes to reckon without love is a fool, pernicious if he were not futile, and no more need be said of him. Eugenics must recognise love, and do it honour and use it, and champion it against those who, in all times and places, are prepared to defile it for Mammon or Bacchus or Priapus.

The foregoing will suffice to show how large a part the social atmosphere must play in eugenic education. Education is not only a matter of formal doctrine. We absorb by imitation and sympathy and suggestion, and young people are highly susceptible to these influences. We require, then, to set up certain standards as those in which we really believe, and then our young people will believe in them also. To preach eugenics to young people while we practise the worship of money is to deceive ourselves, but not to deceive them. They are not so easily taken in. Every ostentatious wedding, every wasteful honeymoon, every newspaper paragraph which chronicles such things, is a lesson to young people that life and love and the future are words, and wealth the only reality.

The Impressing of Eugenic Responsibility on the Mothers of the Future

In the eugenic education of the girl, surely the best method is to place before her the ideal of complete womanhood, which must necessarily include motherhood. And if this motherhood is to be worth while, and is to repay the mother, she must rightly have chosen the child's father. Let no reader suppose that such considerations are unnatural or impossible. For some years past the writer has regularly received from all parts of the world inquiries from correspondents of both sexes who are thinking of getting married, but who wish to be reassured or directed from the eugenic point of view. Such young people have, somehow or other, been indeed educated for parenthood, and the increase of the sense of eugenic responsibility, as thus indicated, is one of the most hopeful signs of the times.

Fatherhood cannot and does not mean to the average young man what motherhood means to the average young woman. But the young man commonly responds to the idea of patriotism. This, too, has its false prophets, by whose services it is much discredited in the eyes of many. Yet there is a true and an instructed patriotism, which stands for the fatherland because the fatherland stands for noble traditions and noble projects; a patriotism which knows that there is no wealth but life, and that there is but one mortal disease of nations, which is *decay of parenthood.*

The Consecration of Young Manhood to a Noble Eugenic Patriotism

It may yet be that the value of fatherhood for the fatherland may be effectively taught to the young men of the next generation, and that when the various alcoholic and other forms of imperialism, which no empire can long survive, have gone to their own place, they may be replaced by a eugenic patriotism, practised as well as preached, and issuing in a consecration of a nation's youth to its service in every high and noble way, of which the first and highest is the renewal of its youth by means of responsible and devoted fatherhood.

WHENCE AND WHITHER?

Have the Sun, the Earth, and Man Any Preferential Position in Immensity ?

MAN'S PLACE IN INFINITE SPACE

BEFORE we study the individual constitution of the sun and his satellites, one tremendous question remains—*Where* is the sun in relation to the rest of things? Astronomically, no question can be more enthralling. Philosophically, it has been thought all-important for man's estimate of himself and his destiny. In our judgment, that is an error, as we shall try to show in concluding this chapter. But the sheer astronomical interest and importance of the question are undeniable, and modern inquiry has afforded us much new information in regard to it.

The problem has several aspects. The sun is a star, we know; just one of what our forefathers called the "fixed stars." And so we may attempt to state its place in space as compared with the other stars. That is the *where* of our problem, and it is sufficient in itself for a lifetime of inquiry. Its answer might prove to be sensational—if, for instance, it could be shown that the sun were, in any way, at the centre of a stellar system, at the centre, perhaps, of the Milky Way, and that the other stars were circling round it. Such a result, which we cannot here accept, as we shall see, but which has lately been argued with great skill and force, would have the practical effect of restoring mankind to the position from which Copernicus deposed us.

Let us note the sequence of human thought on this subject. The obvious view, unchallenged for countless ages, saw man as the master of a central and immovable earth, round which all the inhabitants of the sky visibly revolved, including the sun. The question of "Man's Place in the Universe" clearly answered itself—so clearly that no one even asked it. Then Copernicus showed that the earth goes round the sun, and substituted the *heliocentric* for the *geocentric* astronomy. On this view, not *ge*, the earth, but *helios*, the sun, was the centre of things; and certainly that statement of their mutual relation remains. But the thought of Bruno, and the subsequent observations of astronomers, while confirming the rejection of the geocentric astronomy, involved the rejection of the view that the sun is the centre of all things. On the contrary, the sun had to be regarded as merely one of the multitude of stars, of which we now may say that we know not less than one hundred million bright ones alone.

Such a theory, in the eyes of very many, involves the deposition of man from his apparent place of honour in the scheme and disposition of things. That, precisely, was the head and front of the offence for which Bruno was burnt. His theory was reckoned to be a colossal insult to man and to all man's institutions, not least the Church which killed him. Though we shall seek here to show that this line of reasoning is fallacious and worthless, it is accepted by the great majority of people to-day, as it was three hundred years ago; and some of the most acute and distinguished minds of recent times have tried to find, in astronomical fact, some warrant for man's native estimate of himself and his place in the scheme of things.

We here argue that astronomical fact, which is also material, physical fact, is totally irrelevant, and that man's estimate of himself and his destiny can and must be based upon the facts of Mind, and of Mind alone. But that is not the view which commends itself to any but the philosophical student; and there is no doubt that the unique interest which astronomers and amateurs have always taken in this question depends on their belief that upon the answer to it rests the decision whether man is a negligible accident of the Cosmos, or has in him something older than the elements, and that owes no homage to the sun.

A great astronomical discovery, made by Sir William Herschel more than a century ago, furnishes the most disconcerting and perplexing comment on any results which we may obtain as to the *where* of the sun. We have abandoned the view that the apparent diurnal pilgrimage of the sun across the sky is real; but we find, instead, that the sun has what astronomers call a "proper motion" of his own, which is not due to the earth's daily rotation upon its axis, but is real. Like the other "fixed stars," the sun is not fixed, but moves. If we must grant this, it follows that to prove the sun (and therefore the earth and man) at the centre of all things to-day is to prove him somewhere else to-morrow. Whatever our results for the *where* of the sun, they can afford us no real satisfaction if we have to accept the fact of his proper motion. And we see that a long, new series of inquiries must now be made for the answer to two new questions, which are the *whence* and the *whither* of the sun, the solar system, the earth, and the material substance of men, "buried and breathing and to-be."

Is the Sun Moving in a Straight Line or in a Huge Curve?

First, then, as to the proper motion of the sun. We must remember that this motion is not necessarily, nor even probably, in a straight line for ever. On the contrary, it may be not only curved, but in a closed curve, so that the sun may have an orbit, and returns to its old place in the course of ages, together with its system of satellites, just as Jupiter and his moons do relatively to the sun. This idea of an orbit for the sun has often been discussed, and affords the last possibility of comfort for those who, while bound to accept the sun's "proper motion" as a fact, are still loth to give up the idea that the sun occupies a unique position in the disposition of the heavenly bodies.

Sir William Herschel's work led him to the conclusion that the sun is moving towards a point in the constellation Hercules, a rather straggling, ill-defined constellation in the northern sky, which lies between Corona Borealis, the Northern Crown, and Lyra, with "its star-chord seven." Lyra, or the Lyre, contains an extremely beautiful star, called Vega, which we shall soon be familiar with, when we come to study the constellations, for it is one of the finest stars in the sky. Now, a large number of observations upon the proper motion of the sun have been made since Herschel's day, and we may say that, on the whole, the probable direction in which the sun and we with him are now moving is approximately represented very well by the position of Vega. While this is not the direction indicated by Herschel a century or so ago, it is by no means far from what he stated.

How Different Observations Bear on This Fascinating and Stupendous Question

The difference is probably due to the greater accuracy which modern methods make possible, but there is another explanation which we must remember. If the sun were moving in a curved path, perhaps even in an orbit, its apparent direction would necessarily change from time to time, just as the apparent direction of a runner round a racing-track varies at different times. Thus the difference between the direction of Hercules a century ago and the direction of Lyra to-day might mean the different angle of a runner's approach as he took the curve of some tremendous track, where each "lap" meant billions of miles.

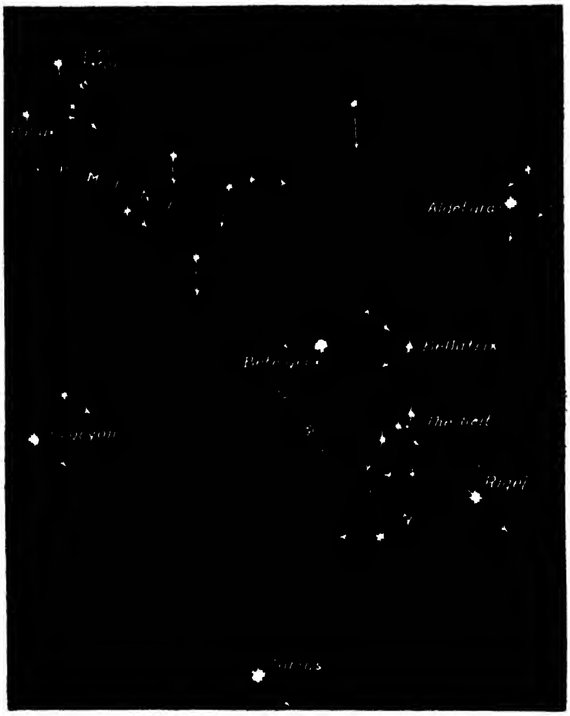
It is not here stated that the difference between Herschel's observations and those of to-day is really due to this cause. We may be practically certain that it is not, and that the path of the sun is not of the character suggested in the foregoing analogy. But obviously it is a matter of the highest interest to ascertain not merely that the sun is, at any given moment, travelling due north, shall we say, as a runner in a circus might, but also to ascertain how, *if at all*, the direction of its movement varies from age to age. We are certain that, though the sun's path can scarcely be straight or rectilinear, what curvature it possesses must be of the most gigantic dimensions.

The Vast Lapses of Time That Must Occur Before Enlightening Comparisons Can be Made

Perhaps not one century nor a thousand centuries might suffice to determine the changes of direction in a path so wide. And, further, gravitation is always at work, and we do not know how the sun's path may be affected by the influence of other stars that may be approaching it or receding from it. These are the reasons why astronomers most desire to ascertain and to record the direction of the sun's proper motion as soon as possible—not that they can hope to understand it, but in order that these records may be compared with those of long ages hence, and thus the real course of the sun's journey may be revealed.

As we saw at the beginning of our inquiries into the universe, our study of motion must always and necessarily be relative. What we call the "proper motion" of the sun is thus its motion relatively to the other stars, and it is by a comparison of the proper motions of the other stars that we are enabled to infer the proper motion of the sun. The principle which we employ is exactly that which is so evident when we travel upon the surface of the earth in a train, and note how near objects rapidly pass behind us, while further objects can be longer seen, and very distant objects seem all but stationary for minutes together. Just so would the stars appear to behave if the sun—and its appendage, the earth, where we have our station—were moving in any direction through space; the nearer stars would appear to move in the opposite direction, while the remoter stars would seem stationary. And that is what astronomers find. When they compare the proper motions of the stars in all parts of the sky, they find that there is an excess of the proper motions in one direction, and a deficiency in the opposite direction, while at right angles to these two directions the average of the proper motions is the same on either side—as is the movement of objects compared on the two sides of a moving train. Astronomers have now compared the proper motions of many thousands of stars in all parts of the heavens, and the result, as we have said, is provisionally to regard the bright star Vega as the goal of the sun's journey, *assuming* that the journey will continue always in a straight line.

Much more difficult, though no less momentous for our expectations of what the future may hold, is the study of the rate at which the sun is moving. This depends upon our accurate knowledge of the distances of the stars against which, so to say, the sun's movement can be traced, and those distances are very difficult to ascertain. Up to about twenty years ago the rate of the sun's proper motion was best estimated at some fifteen miles a second. More recently measurements have been made, by the amazing power of the spectroscope, of the motions of many stars in the direction of the sun's motion, and of many more in the opposite direction. The result is somewhat to reduce our estimate, but we may say that, probably, the proper motion through space of the sun and his family approximates to the rate of about twelve miles in every second of time. This must only be taken as provisional, but still the subject has now been studied for so long, and by so many different observers, with such considerable agreement, that we are quite entitled to take this figure, or anything near it, and make it the basis for further inquiries.



STAR MOVEMENTS IN ORION AND GEMINI

The arrows indicate the proper direction in which each star in these constellations is travelling in space. It will be noticed that on the lines of their direction they form groups.

The importance of determining the speed of the sun's proper motion is evident, for naturally we must try to measure the arena in which it moves, and then we may be able to state how long it would take for the present rate of motion to produce large and momentous changes in the sun's relation to the rest of the universe. But first let us observe what relation the direction of the sun's motion bears to the Milky Way. As we have lately seen, in reference to the theory of Professor Bickerton, the Milky Way is a flat object. It is a somewhat regular, somewhat circular ring of stars, enclosing a mighty gulf, somewhere in which the sun is placed. Now, the most important fact which we have to note is that

the sun's proper motion does not far depart from the plane of the Milky Way. If we imagine the Milky Way to be a ring marked on this page, then the motion of the solar system, now somewhere inside that ring, is not through the page from above downwards, but very nearly in the plane of the paper. Herschel's estimate has been successively revised, and even the late Professor Simon Newcomb's adoption of Vega as approximately in the "solar apex"(as the apparent goal of the sun's motion is called) has been modified by later astronomers; and more and more the opinion is that the solar system is moving through space nearly, if not quite, in the plane of the Milky Way.

The dimensions of the great space in the heavens which the Milky Way encloses are not easily estimated. It is so large that, of course, the only convenient unit for its measurement is a "light-year," the distance which light would traverse in a year; and astronomers have provisionally named figures varying from three to thirty thousand light-years, as suggesting in some degree the probable diameter of the Milky Way. We need not attempt to fix upon any definite estimate, because the *data* for that purpose are still quite inadequate. But we are entitled to compare the probable speed of the sun's proper motion with any reasonable guess as to the dimensions of the Milky Way, in the plane of which we believe that the sun is moving.

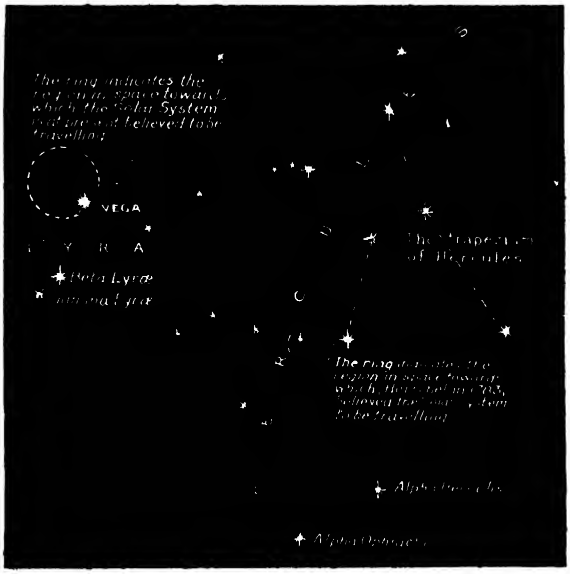
TWO STREAMS OF STARS MOVING IN OPPOSITE DIRECTIONS
The arrows attached to these stars which form the Great Bear indicate the direction in which each is moving, and the length of the shafts the approximate distance they will have travelled in 30,000 years.

Here are two comments by astronomers upon these estimates. They both argue that it is useless to base any important conclusions upon the evidence which seems to suggest that the sun is *now* somewhere near the centre of the Milky Way, for, as one of them points out, at the rate at which the sun is travelling, "Five million years ago we were deep in the actual stream of the Milky Way; five million years hence we shall have completely crossed the gulf which it encircles, and again be a member of one of its constituent groups, but on the opposite side. And ten million years are regarded by geologists and biologists as but a trifle on account to meet their demands upon the bank of Time." The second says: "If there is a centre to the visible universe, and if we occupy it to-day, we certainly did not do so yesterday, and shall not do so to-morrow. The Solar System is known to be moving among the stars with a velocity which would carry us to Sirius within 100,000 years, if we happened to be travelling in his direction, as we are not. In the fifty or hundred million years during which, according to geologists, this earth has been a habitable globe, we must have passed by thousands of stars on the right hand and on the left. Indeed, so far from our having tranquilly enjoyed a central position in unbroken continuity for scores or perhaps hundreds of millions of years, we should in that time have traversed the universe from boundary to boundary." Here, of course, the word "universe" is used to mean the great ring of the Galaxy, or Milky Way, which we have already agreed to recognise as *our* system of stars.

The foregoing quotations will suffice to show that the estimated rate of the sun's proper motion is much more than sufficient to produce huge consequences, within periods of time to which the recent students of the earth's crust have quite familiarised us. In these quotations, taken from papers written only a few years ago, the writers show what extraordinary differences in the sun's position in space would be effected by his proper motion, assuming it to be always in a straight line, within even ten or a hundred million years. But modern geology and chemistry have already far exceeded such figures. Perhaps the latest of all inquiries—though very far from the last—on this subject is based upon the quantity of lead found in the earth's crust, and the supposed rate at which lead is formed by the breaking down of the atoms of radium.

Reckoning on these lines, an investigator has apparently extended the history of the earth to more than a thousand million years. We consider such a figure, and compare it with the statements of the astronomers above quoted, and we find ourselves strongly inclined to the view, ignored by them, but probable on many grounds, that the proper motion of the sun cannot possibly be in a straight line.

It must be curved; it may even be an orbit; or, if it indeed be in a straight line, at a speed which would suffice to carry it sheer through the Milky Way, from side to side, within a fraction of the period required for the evolution of the earth's crust, we are inclined to ask whether, perhaps, the sun is not *one of a company of stars*, all moving together through space, rather than a solitary alien, on some incomprehensible journey through space, which has dashed into this cosmos of stars, and will soon have passed beyond it. And the reader will already be prepared, by his recollection of a few sentences in the last chapter, for the view that the alternative is correct, and that the sun's proper motion is common to the sun and to a large number of other stars, which form, indeed, a great related company or cosmos of stars, now mingled with another such company, to form the great object, perhaps a double spiral nebula, which we call the Milky Way.



THE POINT IN THE HEAVENS TOWARDS WHICH THE SOLAR SYSTEM IS BELIEVED TO BE TRAVELLING

The where, whence, and whither of the sun, and the earth, in relation to the rest of things, thus assumes a more stupendous aspect than ever; and we may best appreciate the nature of the provisional conclusion which was implied in the last chapter by briefly noting the development of speculation on this theme. It is, as we feel "in our bones," the theme of themes for the astronomer, for in it is bound up the where, whence, and whither of the home, the womb, if not the tomb, of man. We talk of the proper motion, the whence and whither, of the sun or of the Solar System, but it is the earth, our earth, of which we are rightly thinking.

One of the most famous and suggestive writers upon astronomy in the nineteenth century, Richard Proctor, profoundly impressed his contemporaries with his books, "Other Worlds than Ours" and "Our Place Among Infinities." His interest lay in the question whether creatures like ourselves could inhabit the planets of other suns. That is what has always underlain the work and the inquiry of the writers on this subject. The celebrated philosopher Dr. Whewell had previously discussed it, in his book on "The Plurality of Worlds." The great Scottish theologian Dr. Chalmers discussed it in his "Astronomical Discourses." Sir David Brewster contributed to it in his "More Worlds than One; The Creed of the Philosopher and the Hope of the Christian." And, in our own century, Dr. Alfred Russel Wallace has published his contribution to the problem, under the title of "Man's Place in the Universe."

The name is legion of the lesser men who have also written on it, and we have not mentioned many other great men who come into the list. But we have cited enough names to show that this problem holds a unique place among the problems of astronomy because of its significance for man, and for many of the most important doctrines of religion. Hence it has necessarily been discussed not merely by the astronomers, but also by men like Whewell and Chalmers and Dr. Wallace, whose interest in the fundamental questions of human life compelled them to consult astronomy for its contribution thereto.

The latest of these writers, and one at least as distinguished as any of them, is Dr. Wallace, whose book was published in 1903,

and excited very great attention at the time. It is here our duty first to state, very briefly, the substance of what Dr. Wallace may be now held to have established, and then to show how the work of the subsequent nine years has advanced our understanding of the question. We are not here concerned with the biological part of Dr. Wallace's book, in which he advances the view that only the earth can be the home of intelligent life. From the standpoint of the astronomer nothing can be less probable than that view; but here our business is not to discuss it, but to acknowledge the services which Dr. Wallace's study of the subject did undoubtedly render to astronomers now nearly a decade ago.

Dr. Wallace set himself the task of gathering and putting together all the relevant evidence which astronomers had themselves provided. No one had undertaken any such task for many years, and Dr. Wallace brought most magnificent powers of mind to its execution. It is easy to state the essential conclusions to which he was led in the astronomical portion of his volume, which here alone concerns us.

The Great Possibility Shown by Dr. Russel Wallace that Our Universe is Finite

They astonished many readers at the time, but they sound quite familiar now, and the reader of this section will be fully prepared for them. None the less is the credit due to the brave veteran who dared to invade the sphere of astronomy and show the astronomers what they had themselves found, just as another illustrious amateur, Herbert Spencer, had taught their predecessors nearly two generations earlier.

In a word, what Dr. Wallace's study of the subject demonstrated was, above all, the extreme probability that what we call the universe of stars, and have hitherto looked upon as the whole of the universe, is *finite*. At this date we are quite ready to accept that view; and we clearly see that it does not involve any unthinkable boundary to boundless space, nor the denial of the possibility of other stellar systems beyond our own. But it does mean that, as our telescopes penetrate space, they reach a point where *our* system of stars ceases. None of the evidence in favour of this view was gathered by Dr. Wallace, but he alone realised that this was the view to which the available evidence must lead us. We have to think of the Galaxy, or Milky Way—which will, of course, be studied here in detail later—as the ground-plan of our system of stars. The movements of the stars that compose it, and of our sun, are in the plane of the Milky Way, or near it. In various parts of it we can observe groups of stars which seem to be moving together in a connected fashion, but these "star-drifts," as Richard Proctor called them, evidently have some relation to the rest of the system. In short, the company of stars that we know *is* a system, and not a vast, infinite aggregate, without a plan. No one before Dr. Wallace had shown how clearly this is so; for only when the work of many different astronomers, in many different fields, is collated do we see how the various facts of the sky, the distribution and the motions of the stars, though at first sight inexplicable, are evidently related and interdependent in some unknown way.

The Parts of the Sky where we Seem to Come to the End of the Stars

Notably, Dr. Wallace displayed, in striking fashion, the evidence that our cosmos of stars is limited in space. We increase the power of our telescopes and we find more stars, but there is a limit to the process. After a time we do *not* find so many more stars as we should expect. They begin to thin out most significantly, and with considerable regularity. Further, there seem to be places where the telescope can peer beyond the limits of our starry system into empty space. These places contrast so sharply with others, where the stars are closely crowded, as in the most populous part of the Milky Way, that their reality cannot be questioned. Probably the supposed rifts in the Milky Way, through which we may argue that we see beyond the limits of our starry system, are not rifts at all, but indicate the presence of dark matter, which cuts off our view of the stars behind them. But, even so, the evidence, as gathered by Dr. Wallace, was extremely powerful, and may fairly be said to have demonstrated that our cosmos of stars is not infinite, but finite.

The Great Conception that there May be a Centre to All the Things we See

The importance of this conclusion, which we may accept for our present purpose without further discussion of the evidence, is obvious from the point of view of the where, whence, and whither of the sun and his family. If the known universe of stars be infinite, extending beyond the limits of telescopic vision in all directions without end, then it would be idle and meaningless to claim for any one of its constituent stars a unique position and relation to the rest.

An infinite number of similar positions and relations might be occupied by other stars beyond our vision, whatever we might be able to demonstrate regarding those we can see. An infinitely extended collection of stars could have no centre. There can be no mid-point in infinite space or infinite time; there being no boundaries, there is nothing for any centre to occupy the middle point between.

Why May not Even our Own Sun be the Centre of All Things?

But if we can delimit the stellar universe, descry its shape, and indicate its numbers of inhabitants, and if, further, its form is found to be approximately circular, then, indeed, it is quite possible that any one of its hundred million bright suns, perhaps even our own sun, might occupy a unique position in relation to all the rest, perhaps in the very centre, perhaps circling alone round an unoccupied centre, and shone upon at something like equal distance, by the millions of stars arranged in a mighty circle round it.

We shall not follow Dr. Wallace any further, however, for we are now compelled to recognise the work which astronomers have done since he wrote. Dr. Wallace refers to some important work done by Professor Kapteyn, of Gröningen, now twenty years ago, but Professor Kapteyn has done much more important work in the last few years, and allusion has already been made to it here. He, and subsequently several other astronomers, have shown that the undoubtedly limited and orderly collection of stars which comprise the system of the Milky Way belong to two distinct groups, and these two groups, two mighty star-drifts, are passing through and past each other. They are really two systems of stars, each a cosmos within the Cosmos; and Professor Bickerton may be right in his view that their collision has produced the double spiral nebula which he declares to be the real form and nature of the Milky Way. To one of these two stellar systems, it would now appear, our sun and ourselves belong.

The Absence of Evidence to Show that Our Sun is in Any Way Unique

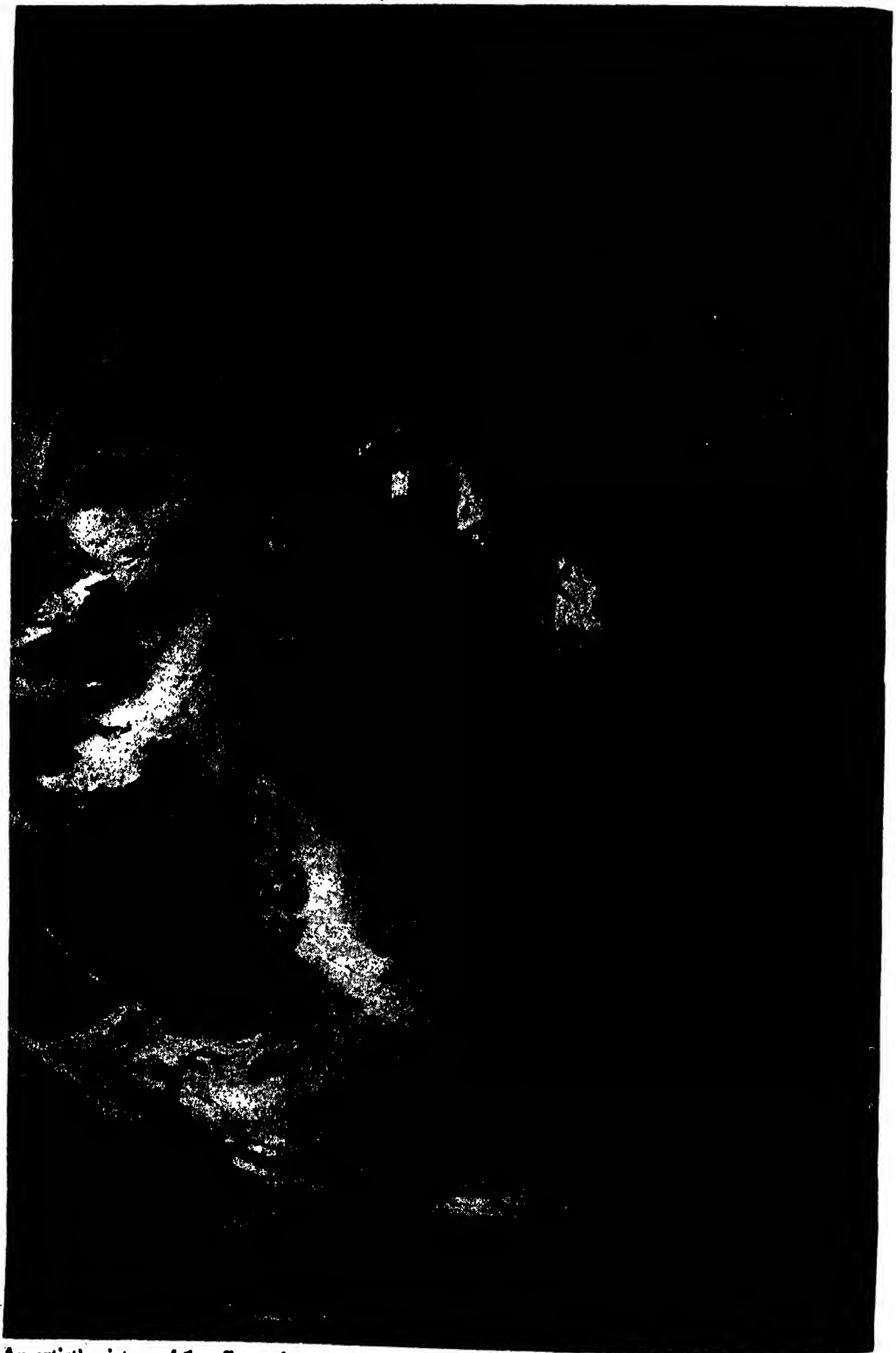
All preceding conclusions and speculations must yield to these new discoveries. The student of the history of astronomical thought and speculation will still be compelled to read Dr. Wallace's book, and he will learn much therefrom, like all his predecessors. But its main astronomical conclusion, as regards our sun, is no longer tenable at all, though, as we have seen, its conclusion as to the finiteness of our stellar system is now accepted by astronomers. We cannot look upon our sun as in any way unique, either in its own composition and constitution, which we are about to study, nor in its position in the scheme of things, past, present, or to come. It is simply one member of a vast multitude of suns, constituting an allied system of stars, which has been travelling through space, whence and how long we know not, and has come into collision with another such system, travelling in an opposite direction.

Such, according to the best and fullest knowledge of the heavens yet attained by man, is the answer to the *where, whence, and whither* of the sun, and therefore of the earth, which is just a very much smaller brother of the sun. And now we have to ask ourselves, in conclusion, what this means for the distribution of life in the universe. Had it been shown that man's planet is unique, or, at any rate, that it is one of the few planets of an unique sun, we might have framed another answer to this question—a prouder answer, though not necessarily a wiser or a more splendid.

Man's Glorious Position in the Cycle of Life, Though He May Not be Unique

As it is, we are forced by this most recent verdict of astronomy to a conclusion which only very shallow men will regard as belittling to their kind. It is that, though life must necessarily adapt itself, wherever it exists, to the conditions in which it finds itself, and though we therefore cannot expect life to assume on any planet of any sun but our own the forms which it assumes here, yet at a million or a million million points throughout that disposition of matter which we call the universe something may take material clothing upon itself, and show itself as life.

The creature we call man, then, is simply the particular manifestation on our earth of that universe of mind which everywhere interpenetrates the universe of matter. When and where the conditions favour, mind becomes incarnate in matter, as in any one of us. So it may be in other worlds, extant, extinct, or yet to be. Just as the manifestations of mind on our planet are some higher and some lower, so also we cannot say to what heights they may extend on other worlds, past, present, or to come. And while such conclusions may rightly trouble man when he dares to be presumptuous, they exalt him also, proclaiming his kinship with all things and his being's identity with the soul which is the veritable substance of the universe.



An artist's picture of the effects of a tornado in North-Western Australia, when the atmosphere seemed to sweep over the Earth's surface in a spirit of passionate destruction.

ATMOSPHERIC MOVEMENTS

How the Heat and Flow of the Air are Measured and How Weather Wisdom is Sought

GALES FROM THE WHIRLING EARTH

We may ignore the weight of the air, or the humidity of the air, or the radioactivity of the air, but the temperature of the air forces itself upon our notice. A temperature of 125 degrees Fahrenheit in the shade, or − 40 degrees Fahrenheit in the shade, refuses to be ignored. Nor is the temperature of the air important merely in its relation to our skin and our circulation; it has such far-reaching consequences as tempests and typhoons, as "trades" and "anti-trades." Heat it was that took Columbus to America; heat it was that took Sebastian d'Alcano round the world, just as certainly as it is heat that takes the "Mauretania" across the Atlantic.

Before, however, we discuss the far-reaching consequences of the heating and cooling of the air, it will be well to look at the thermal facts themselves. In the first place, how is the heat of the air measured? It is measured usually by means of instruments known as thermometers, which are constructed on certain principles which we shall now briefly describe.

The ordinary thermometer consists of a little bulb ending in a closed tube. There is enough mercury in the bulb and tube to fill the bulb and extend some way up the closed tube. The tube above the limit of the mercury is emptied of air, so that it is practically a vacuum. When heat is applied to this bulb and tube of mercury, the mercury expands, and the upper limit of the mercury in the tube rises and rises in proportion to the heat applied. By grading the tube accordingly, and marking the point to which the expanding mercury rises, we can measure the heat. Instead of mercury some other expansile liquid such as alcohol may be used. Two thermometers, differing in their graduation, known as Fahrenheit and centigrade, are in common use.

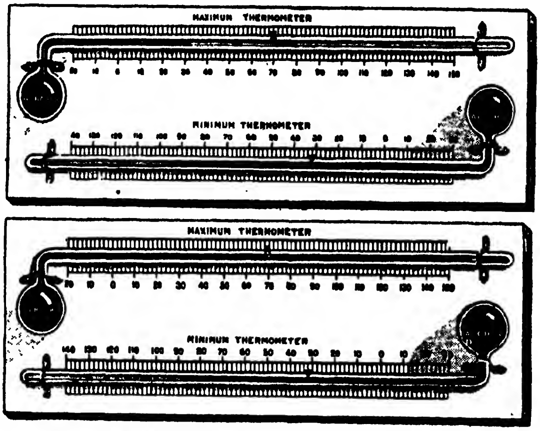
The Fahrenheit thermometer divides the extent of expansion between the freezing and boiling points of water into 180 degrees, and, marking the freezing-point 32, marks the boiling-point, accordingly, 212. Its zero is thus 32 degrees below its freezing-point. The centrigrade thermometer, on the other hand, divides the expansion between the freezing and the boiling points of water into 100 degrees, and, marking the freezing-point 0 degree, marks the boiling-point 100 degrees. A hundred degrees on the centrigrade scale thus equals a hundred and eighty degrees on the Fahrenheit. On both thermometers the degrees are marked up beyond the boiling-point, and down below the freezing-point. Mercury freezes at 40 degrees—*i.e.*, 72 degrees Fahrenheit below the freezing-point of water—and therefore for recording very low temperatures an alcohol thermometer is better than a mercury one. A thermometer known as the Réaumur is also used. In the Réaumur thermometer the freezing-point of water is marked 0 degree and the boiling-point 80 degrees.

Thermometers are graduated by first plunging them into melted ice, and marking the point to which the mercury or other liquid contracts, and then putting them in the vapour of boiling water, and marking again the point to which the mercury or other liquid expands. The length so marked is then divided into 80, 100, or 180 degrees, according to the thermometer desired.

Thermometers, knows as thermographs, are made which continuously register the temperature by means of a pen tracing on a moving drum. In such an instrument the expansile liquid fills a curved, closed tube, and as the liquid expands it straightens the tube in its effort to make more room. One end of the closed tube is fixed, but the other end is free, and to this free end is

attached the registering pen to record its movements; and its movements recording the expansile movements of the tube necessarily record the heat to which the liquid has been exposed.

In order correctly to determine the temperature of the air, the thermometer must be screened from the direct rays of the sun, since the sun would heat the thermometer much more than it heats the air. The sun, indeed, passes through the air and heats it comparatively little, and the heat of the air is due more to the radiation of heat from the earth than to the direct rays of the sun. As we ascend above the earth accordingly the temperature of the air steadily falls. Thus a free balloon carrying a self-registering thermometer which was sent up from Trappes, in France, at a temperature of 50 degrees Fahrenheit, registered a temperature of −58 degrees Fahrenheit at a height of six miles; and a balloon sent up from Strassburg, at a temperature of 43·3 degrees Fahrenheit, registered a temperature of −65 degrees Fahrenheit at about the same height.



THERMOMETERS THAT RECORD HEAT AND COLD

These pictures show the working of maximum and minimum thermometers, the indicators, x and v, marking the highest and lowest temperatures reached. In the upper picture the minimum thermometer is at 32 degrees, the lowest point reached overnight. The alcohol carried the indicator, v, to this point, and left it there when the temperature rose, as in the lower picture. In the maximum thermometer of the lower picture, the mercury is at the supposed highest temperature of a day. It has pushed the indicator, x, to 70 degrees, and when it shrinks to a lower temperature, as in the upper picture, the indicator is left at 70.

Apart from height, the temperature of the air is in proportion to the direct heat of the sun; and this, as we have already explained, varies with the obliquity of the sun's rays. But the temperature of the air also depends on the nature of the surface on which the sun-rays fall. Thus land is more quickly heated by the sun than water, and radiates heat to the air more quickly. Water, on the other hand, stores more heat than land, and radiates heat to air when the land is quite cold. It is for this reason that sea modifies both the heat and the cold of the land, and that inland places have greater extremes of temperature than places by the sea. The sandy soils of deserts may be heated almost to boiling-point by the sun, and when the hot sand is raised by simooms the temperature of the air may rise to 125 degrees Fahrenheit, or even more.

Such disturbing factors as these, especiall the irregular distribution of land and water render the distribution of heat rathe irregular, and only in a rough and genera way can we assert that the nearer th equator the greater the heat. Meteoro logists have constructed very interestin maps with lines known as "isotherma lines" running through places with the sam mean annual temperature, and these line are found to have wavy, undulating courses and not to run parallel to the equator. Th median line of the zone of greatest mea heat is found to run not through th equator, but slightly north of it, and it margins are wavy, with tongues runnin northward into India, and southward int Africa and Sout America.

In January th Shetland Island are on an isother that runs throug the Souther American State in July they ar on an isother that runs throug Alaska. Owing t the warm, mois winds from th Atlantic Ocea places on th West of Englan lie on the sam isotherm as place further south o the East.

Thus, Anglese has the same mea temperature as th mouth of th Thames, and Skye has the same mean tem perature as the mouth of the Tees. S great is the influence of the warm, we Atlantic winds that if they were to fai us the mean winter temperature of Londo would fall from 38° Fahr. to 22° Fahr. and the winter in Edinburgh would b as severe as the winter in Greenland. W shall return to this subject when we com to speak of climate and climatic changes.

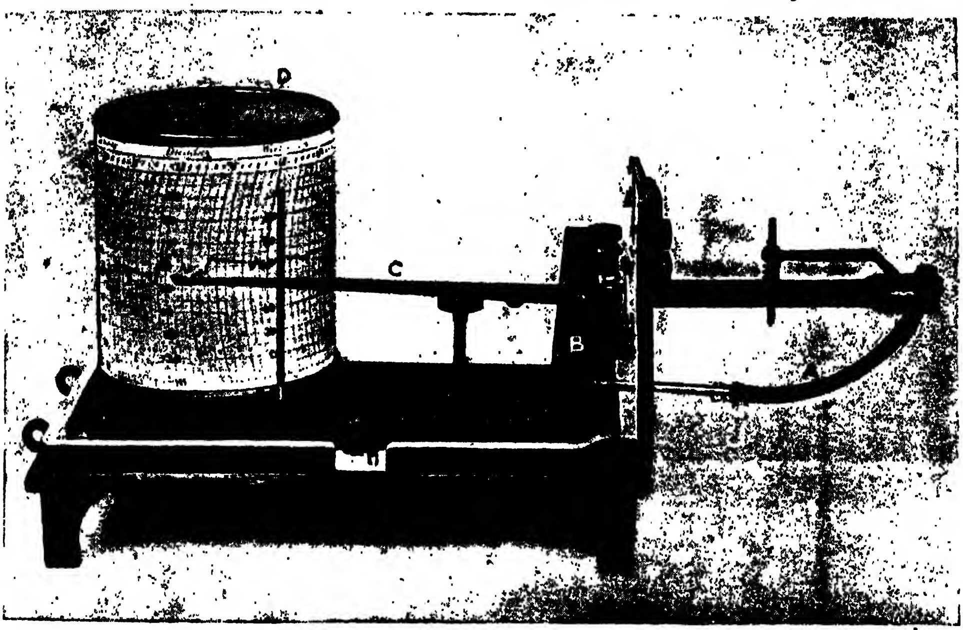
The atmosphere, then, is heated in thi irregular manner by the sun, and the resul is wind. Were it not for the unequal heatin of the atmosphere, it would be stagnant a a mill-pond; but the sun heats and expand it and fills it with water-vapour, and give it tides and currents like a sea.

The great tides of the atmosphere are the

"trades" and the "anti-trades," and they are simply hot and cold currents of air running between the Poles and the equator, and deflected by the motion they receive from the whirling earth. Let us look into the physics of these great heat-currents.

The hottest air is the air in the belt we have already mentioned which runs round the earth a little north of the equator, and this belt is the mainspring of the great atmospheric current. The air of this belt being heated and laden with moisture, expands and rises, and is heaped up above the general surface of the atmosphere. Naturally it does not remain heaped up, but flows away towards the Poles, while the winds north and south from the equator, but in no case is the direction due north or due south. How is this?

Let us consider the relation of the atmosphere to the earth's rotation. The atmosphere is bound to the earth by gravitation, and, apart from disturbing factors, earth and atmosphere turn together as if a continuous whole. The atmosphere above the equator whirls round with the equatorial belt, which, as is well known, is larger than the Polar belt. The atmosphere, likewise, in the Arctic circle whirls round with its smaller circle of latitude, completing a much smaller circuit in twenty-four hours, and therefore moving much more slowly than the air



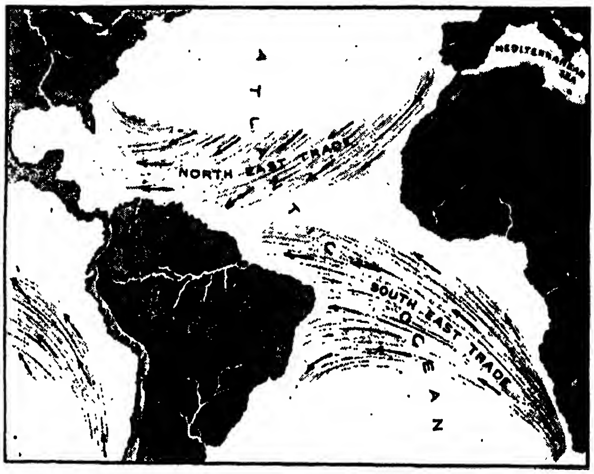
THE THERMOGRAPH, THAT RECORDS THE VARIATIONS OF TEMPERATURE
The curved tube, A, is filled with liquid which, as it expands and contracts, moves the marker, C, up and down, by means of the levers at B. On the drum, D, revolved by clockwork, is a chart on which a week's record of the variation of temperature has been marked.
This photograph is reproduced by courtesy of Messrs. Negretti & Zambra.

heavier, colder, denser air from the Poles rushes along the surface of the earth towards the equator in an effort to restore equilibrium. It is much the same as happens when a window is opened top and bottom in a room with heated air. The heated air pours out at the top and the cold, denser air rushes in at the bottom to restore the balance. The heated expanded air, indeed, may be regarded as a partial vacuum.

The heated upper air floating north and south from the heated zone constitutes the "anti-trade" winds; while the cold tides flowing from the Poles are the "trade" winds. The trade winds run north and south from the Poles, and the anti-trade above the equator. In general, it is plain that the atmosphere moves more and more slowly in its eastward rotation with the earth the farther we recede from the equator, and the nearer we approach the Poles. Now, hot air rising from the equator and flowing towards the North Pole retains as it flows the rapid eastward motion it had when it started; and this motion as it reaches northern latitudes is quicker than the motion of the surface of the earth in these latitudes. Accordingly, the air flowing northward deviates eastward across the more slowly eastward-turning surface of the earth. That is to say, it seems to come from the north-west and to be a north-west wind.

Hence the anti-trade flowing in the upper atmosphere northward from the equator is a north-west wind. The anti-trade, again, flowing southward from the equator, becomes on the same principle a south-west wind.

Let us see next in what direction the trade winds deviate, and why. The north trade wind starts from the North Pole, and flows in the lower layers of the atmosphere towards the equator. It starts with a very slow eastward drift, since in the northern latitudes the atmosphere is carried only slowly eastward, and the result is that, as it flows southward, the more quickly rotating lower latitudes outstrip and pass it. The result is a wind that seems to come from the north-east. This is not quite easy to understand at first, and an illustration will make it plainer. Suppose a steamer steaming east at twenty miles an hour, and a west wind blowing eastward at ten miles an hour, in what direction will the wind seem to be blowing to people on the deck of the steamer? Obviously, though the wind is an eastward or west wind, the quicker motion of the steamer creates an east wind, and the wind really coming from the west and blowing to the east—a west wind, that is to say—seems to be coming from the east and blowing to the west, an east wind, that is to say. In just the same way, though the trade wind is coming from the west and going eastward, the earth is rotating eastward faster still, and so outstrips the west wind, and creates an east wind of its own.



THE DIRECTIONS OF THE ATLANTIC TRADE WINDS

In like manner the trade winds blowing from the South Pole appear as south-east winds.

We have said that the trades and anti-trades retain the velocity imparted to them at their start by the velocity of the earth. If we toss up a ball in a railway carriage when the train is moving, the ball retains the forward momentum imparted to it by the train, and falls on the floor of the carriage, even though the carriage floor may be moving forward at the rate of sixty miles an hour. And on the same principle the wind retains its initial velocity.

But in the case of the trades and anti-trades, another law comes into play. As the trade winds proceed northward they approach nearer and nearer the axis of rotation of the earth, N C being the axis of rotation of the earth, and K B A being the trade wind at various stages of its northward journey, it is plain that B T is less than K C, and A S less than B T. This approach of the wind nearer to the centre of rotation quickens its speed. This may be easily illustrated by attaching a weight by a string to a stick, and twirling the weight round the stick, so that the string winds up, when it will be found that the weight circles the stick more quickly as the string shortens. Accordingly, the trade wind not only retains its initial velocity, but acquires more speed eastward as it proceeds northward. By the same law, the anti-trades coming from the Poles towards the equator, and receding from the axis of rotation as they proceed, must slow down.

But an apparent anomaly remains to be explained. The trade winds blow for only about 30° north and south of the equator; then comes a zone of calm, and then south-westerly winds and north-westerly winds in the north and south hemispheres respectively. How is this? This apparent anomaly is due to the conflict between the trades and the anti-trades. At the equator the heat lifts the anti-trades up out of the way of the trades; but as the anti-trades cool, they descend and mingle their north-east currents with the trades. At first the conflict is even, hence the zone of calms, but in time the north-east currents of the anti-trades prevail, and the result is westerly winds. The warm south-west winds that visit our coast probably commenced their career at the tropics.

Though a great part of the anti-trade wind cools and descends, there is always

an upper layer which proceeds towards the Poles, and on the tops of all high peaks we can always find westerly anti-trades, even when north-easterly or south-easterly trades are blowing below; and volcanic dust and clouds when high in the air always go westward. In Java the smoke from a crater 9000 feet high always goes westward; while for six months the clouds lower down drift in the opposite direction.

After the trades and the anti-trades, which are called constant or regular winds, come the so-called seasonal or periodic winds such as the monsoons. Monsoons are winds periodically generated by the heating of the air above tracts of hot land, and the consequent rising of cooler air from the sea.

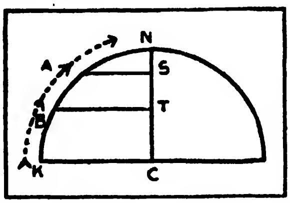
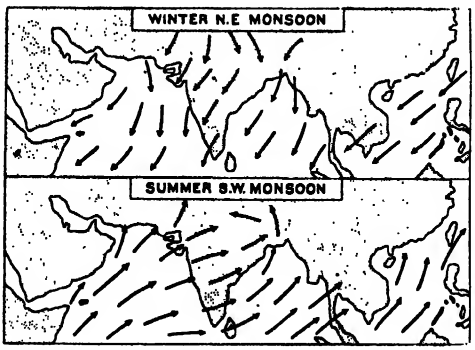


DIAGRAM ILLUSTRATING A LAW OF TRADE WINDS

The Indian monsoons are particularly well known, and are produced as follows. The land of India becomes so heated during the summer time that the air over it becomes hotter than the equatorial air, and accordingly hot air is drawn from the equator to India. Again, since the air drawn from the equator retains its great equatorial eastward velocity, the wind seems to come from the south-west; hence we have in summer the south-west monsoon. In winter the current is reversed, and there is a north-east monsoon blowing from the land.



THE MONSOONS, OR SEASONAL WINDS OF SOUTHERN ASIA

It may be a little difficult at first to understand the behaviour of these great winds, but the general principles of their movement is clear: they are the results of the irregular heating of the earth's surface by the sun, and the deviation in direction, owing to the rotation of the earth, is of secondary importance.

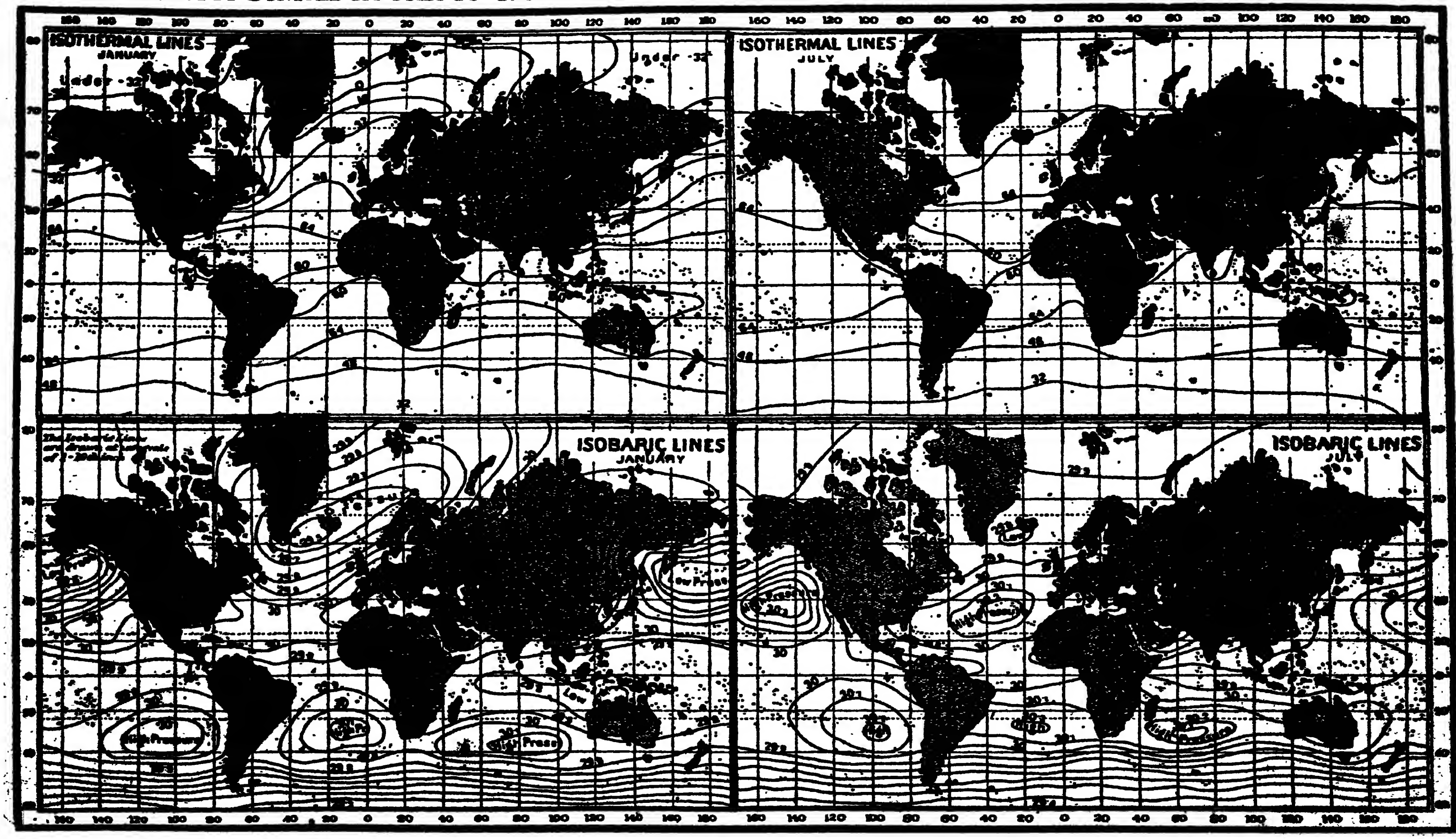
Not only the great winds but the small winds are due to inequalities in heat. In the daytime on the sea coast there is a breeze from the sea, since the land is hotter than the sea, and heats and expands the air over it, but after the sun sets, and the heat has radiated from the land, the sea is hotter than the land, and a breeze therefore blows from the land to the sea. Again, at high altitudes during the day, when the high land is heated by the sun and rendered hotter than the plains, a breeze blows uphill from the cooler valley land, but at night, since the high land grows more quickly cool than the low land, the direction of the wind is reversed. The *mistral* of the Riviera is a cold north-westerly wind which rolls down on the plains from the cold summits of the Cevennes and the Maritime Alps.

But, besides the great trade and anti-trade tides, and the fluctuations due to such known alternations of heat and cold as we have mentioned, the ocean of air, like the ocean of water, is full of travelling whirls and eddies of various sizes, and it is these that constitute the ordinary winds and gales, and to a great extent determine the weather. Any considerable alteration in local air-pressure, whether the alteration be due to heat or water vapour, or both, is followed by wind. If the pressure be lowered, air flows in all round to equalise the pressure; if the pressure be increased, air flows outwards to restore equilibrium. The inward flow of the air toward a centre of low pressure is called a "cyclone," or cyclonic movement, and the outward flow of the air from a centre of high pressure is called an "anti-cyclone," or anti-cyclonic movement.

In both cases, however, the air does not flow straight in or straight out, but proceeds in a spiral course. The spiral motion is caused by the earth's motion, and varies in direction. In the northern hemisphere the spiral whirl of a cyclone flows inwards in a spiral which turns in the opposite direction to the hands of a watch; while the spiral whirl of an anti-cyclone turns in the other direction. In the southern hemisphere, on the other hand, cyclones and anti-cyclones whirl in just the reverse directions, the southern cyclone turning in the direction of the hands of a watch.

The following practical rule, known as Professor Buys Ballot's law, gives the direction between wind and pressure for the northern hemisphere: "Stand with your

PLACES WITH SIMILAR HEAT & AIR-PRESSURE ROUND THE WORLD & THROUGH THE YEAR



ISOTHERMAL LINES SHOWING HEAT OF EQUAL INTENSITY ALONG THE COURSE OF EACH LINE, AND ISOBARIC LINES GIVING BAROMETRICAL PRESSURES

back to the wind, and the barometer will be lower on your left hand than on your right; hence it follows that if you stand with the high barometer on your right and the low barometer on your left, the wind will blow on your back. In the southern hemisphere the rule must be reversed, 'right' put for 'left' and 'left' for 'right.'"

An anti-cyclone is usually a very stationary eddy, and the air descending in its spiral is free from moisture; it is thus usually associated with good weather. In summer anti-cyclonic weather is calm, cloudless, and sunny; and in winter calm, cloudless, and frosty.

A cyclone is not a stationary eddy; it is always moving, and sometimes moves at a great rate. It usually brings rain and cloudy weather, since the vapour in the rising air condenses as it rises.

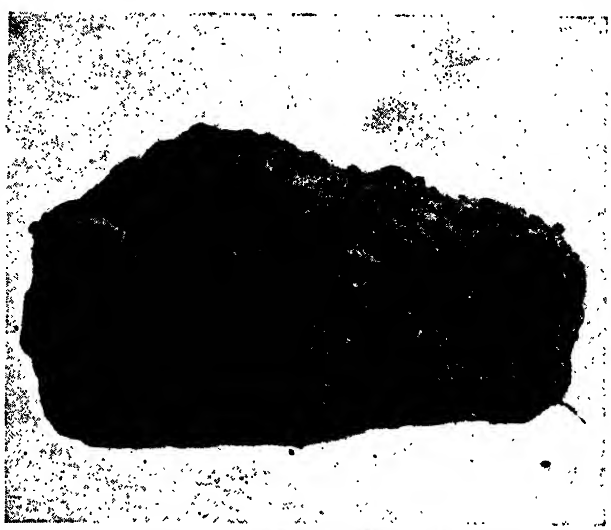
Since fall of pressure is usually associated with bad weather, and rise of pressure with good, barometers evidently may be used to foretell the weather. But in most cases the important thing is not the mere rise and fall, but the rise and fall relatively to surrounding areas, and this can be found out only by a comparison of local readings; and nowadays such comparison is made by charting on a map a collection of readings telegraphed by various meteorological stations. In this way we can draw curved lines of equal pressure, which are called "isobars," and the charts so drawn will show cyclones or anti-cyclones as in the diagrams.

Isobars are usually drawn to indicate successive differences of pressure equal to that of one-tenth of an inch of mercury. The closeness together of such isobars is evidently an indication of the gradient of the fall, and the gradient is stated as so many hundredths of an inch of barometric pressure in a distance of 60 nautical miles (one degree). Thus, if two barometers 60 miles apart differ by $\frac{3}{100}$ of an inch, the gradient is said to be 3. The deeper the depression and steeper the gradient, the stronger the wind.

Thus, from a weather chart we are able to foretell weather to some extent. If we know that the central depression of a cyclone is advancing in a certain direction, at a certain rate, we can tell approximately its future course, and the date of its arrival at various districts. Over a large continent like the United States, prediction is comparatively easy, but in Great Britain it is very difficult; for even if a depression be detected as it touches the west coast, one can hardly tell in what direction it has come, or at what rate, and therefore one cannot predict its future career. During the wonderful spell of anti-cyclonic fine weather in Britain during the summer of 1911, various depressions were reported as coming, but they always turned aside and failed to disturb the weather.

In some instances, too, cyclones advance so rapidly that there is hardly time to foretell them. In a great storm in 1903 a cyclone reached the West Coast of Ireland one morning, and before evening it had spread over nearly the whole of the British Isles. Next morning it was in Holland.

When a cyclone has a very deep and steep central depression, and whirls and advances with great rapidity, it becomes what is known variously as a typhoon, hurricane, whirlwind, simoom, or tornado. Such violent whirls are always caused by the rapid local heating of the lower layers of air, so that a column of hot air rushes up like the hot air that rushes up a furnace chimney. Miniature tornadoes are often seen whirling about on hot deserts, or even on hot roads, raising little fountains of dust as they whirl, and in this country they are seldom seen except in such miniature form.



HOW WIND AND RAIN WEAR AWAY ROCK

In this fragment the softer limestone has been worn away, leaving the harder fossils imbedded in it to stand out in relief.

Sometimes, however, even in this country they are large enough to knock down buildings and trees, and to do considerable damage. On the Continent, in North America, in the West Indies, in the China Sea, in the Bay of Bengal, on the East Coast of Africa, and on the Sahara, violent and destructive cyclones are far from uncommon. Professor N. S. Shaler thus describes a destructive North American cyclone:

"In its path over the surface, the circling movement of the writhing air, and the sucking action of the partial vacuum in the centre portion of the shaft, combine to bring about an extreme devastation. On the outside the whirl of air, which rushes in a circling path towards the vortex, overturns all movable objects; and in the centre these objects, if they are not too heavy, are sucked up as by a great air-pump. Thus the roofs of houses, bodies of men and animals, may be lifted to great elevations, until they are tossed by the tumultuous movements beyond the limits of the ascending current, and fall back upon the earth. When the centre of the whirlwind passes over a building, the sudden decrease in the pressure of the outer air often causes the atmosphere which is contained within the walls suddenly to press against the sides of the structure, so that these sides are driven quickly outwards as by a charge of gunpowder."

And William Ferrel gives the following account of a tornado in Minnesota:

"The tornado struck the Mississippi River at a point opposite to the village of Sauk Rapids, and fishermen who were in full view of the crossing aver that for a few moments the bed of the river was swept dry; and in corroboration of this remarkable statement they showed me a marshy spot where no water had been before this event took place. Two spans were torn away from the substantial waggon-bridge below the rapids, one span being hurled up-stream and the other down it by the rotatory motion of the blast, great blocks of granite being also torn bodily out from the piers. The large flour-mill near the bridge was levelled. The depot of the Northern Pacific Railway was demolished, and the central portion of the village itself was attacked with the greatest violence. Being the county seat, the courthouse was located here, a substantial structure, of which only the vault, six iron safes, and the calaboose were left—the latter turned upside down. A fine new schoolhouse, costing 15,000 dollars, was completely swept away. The Episcopal church was so utterly ruined that the sole relic thus far found is a battered Communion plate. The floor of the skating-rink is all that is left of that structure. Stores, hotels, a brewery, and four-fifths of the residences in the village were scattered as rubbish along the hillsides, or borne away for miles through the air."

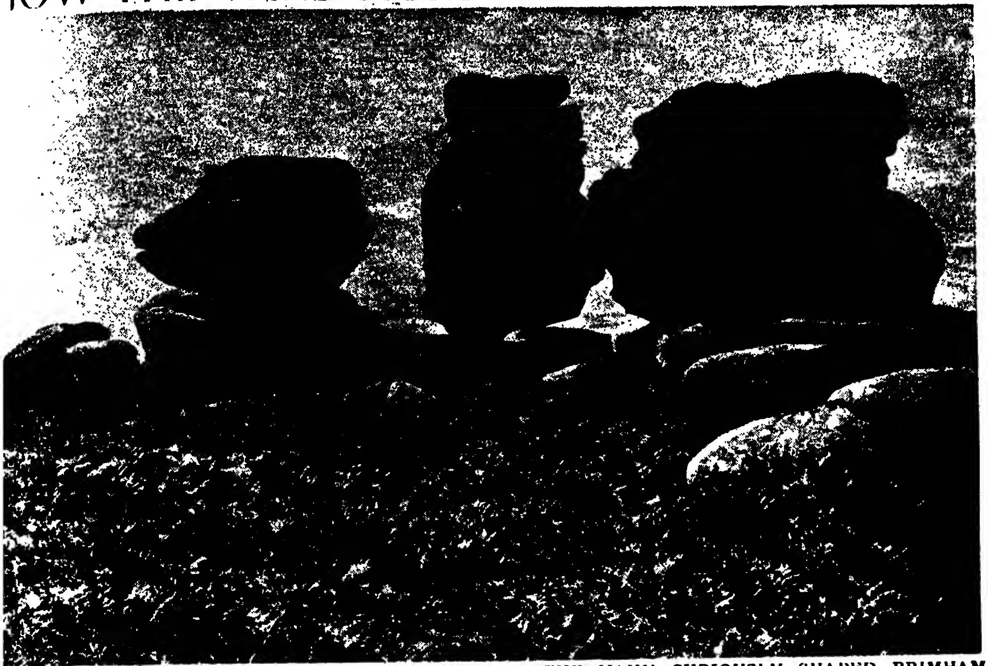
Another sensational example occurred in Illinois on June 4, 1877, where a man saw a tornado strike his house, and "the house appeared to go up bodily and plunge into the cloud. Only a very small portion of it was ever seen afterwards to be recognised."

The average rate of surface wind on land is from six to twelve miles an hour. On sea and at high altitudes the velocity of the wind is greater; and in winter the cirrus cloud, which is one of the upper clouds, travels over ninety miles an hour. Tornadoes sometimes go hundreds of miles an hour. Winds are named breezes, gales, etc., according to their rate; and the well-known Beaufort Scale, as lately modified, is given below:

Force of Wind or Number of Sails.	Description of Wind.	Velocity in Miles per Hour.
0	Calm	3 miles per hour
1	Light air	8 " "
2	Light breeze	13 " "
3	Gentle breeze	18 " "
4	Moderate breeze	23 " "
5	Fresh breeze	28 " "
6	Strong breeze	34 " "
7	Moderate gale	40 " "
8	Fresh gale	48 " "
9	Strong gale	56 " "
10	Whole gale	67 " "
11	Storm	75 " "
12	Hurricane	90 " "

The Beaufort Scale was arranged by Admiral Sir Francis Beaufort in 1805. It gives the relation between the velocity of the wind and the amount of sail a ship could carry.

The winds of the world are the daughters of the sun, and are full of the sun's energy; and a good deal of the energy of the sea, its waves and its currents, are due to the action of the wind. Every puff of wind means a wave; it pushes up the water before it into a heap, and this swings up and down and is repeated across the sea. Strong winds make huge waves, but waves are never mountains high; the highest sea-waves that have been measured measure only 50 ft. from trough to crest, with about 400 yards between successive crests. It



THE MONKEY'S FACE AND THE PULPIT, TWO OF THE MANY CURIOUSLY SHAPED BRIMHAM ROCKS, NEAR PATELEY BRIDGE, YORKSHIRE

TOWAN HEAD, NEAR NEWQUAY, CORNWALL, AN EXAMPLE OF ROCK SCORED BY WIND-BLOWN SAND TILL IT HAS A FALSE APPEARANCE OF STRATIFICATION

must, of course, be understood that waves do not travel forward—they merely rise and fall. But the wind does more than produce stationary waves; it also produces what is called surface drift—*i.e.*, it drives the top layer of water before it, and, in fact, skims the surface of the sea as one skims the cream off milk. In this way currents are set up in various parts of the ocean which, more or less, agree in direction with the direction of the prevailing wind. Pieces of wood, and nuts, and seeds are sometimes carried right across the Atlantic by surface drift, and, as is well known, Columbus received his first intimation of the nearness of land through objects drifting in the Atlantic. The best-known surface drift current is the Gulf Stream, but, as we shall see when we come to deal with the ocean, there are many smaller currents all over the world.

When the wind blows off the land the sea near shore is colder, as bathers know, than when it blows landward. The reason of this is that a seaward wind blows the warm surface layers seaward, off the top of the sea, while a landward wind drives the warm surface layers landward.

The Wasting Power of Wind-Blown Sand over Rocks

When we come to speak of climate, we shall see that the direction of the prevailing wind is a very important factor in climate. All meteorological stations possess instruments called anemometers, which register automatically the force and the direction of winds.

The wind troubles not only the sea—it also gnaws away at the land. Even as it carries along the salt spray of the sea, so does it carry along the sand of the seashore. On a windy day the wind along the shore is full of sand, and this sand is Nature's file and sandpaper, wherewith she polishes and glazes the rocks and crags of the sea coast. But not only does the sandpaper polish—it also wears away: here and there we find rocks, such as the tors of Devon and Cornwall, rubbed away into strange shapes by the friction of wind and sand. In Kerguelen Island all the exposed rocks are grooved from west to east by wind-driven sand.

By the accumulation of sand, again, hillocks of sand, or "dunes," are formed. On the British coast dunes rarely exceed 40 or 50 ft. in height, but in other parts of the world much higher dunes are found. Around the Gulf of Gascony, in France, there is a long, ridged dune almost 300 ft. high at its highest point; and the dunes of Cape Bojador, on the north-west coast of Africa, and of Cape Verde Island, attain a height of from 390 to almost 600 ft.

But sand does not always end in dunes; sometimes it invades fertile country and overwhelms, as in Bermuda, gardens and fields and woods.

The Ravages of Sand-Waves on an Exposed Coast

In 1839 the church of Eccles, on the coast of Norfolk, was buried up to its belfry tower in sand; in 1892 the sand-wave had been blown landward past it, and it had to be unburied again. On the Cornwall coast, Constantine's church was buried in sand for seven centuries, to be finally uncovered again in 1835. On the east coast of Aberdeenshire, some centuries ago, the whole parish of Forvie was buried in sand. Only the old kirk is visible; not a sign of any cottage is left. Mr. Masson, a "Preacher of the Gospel," considered that "the folks of Forvie suffered this heavy judgment because they were Papists and grossly ignorant." The local legend, however, attributes the misfortune to the maledictions of an heiress who was sent out to sea by a wicked uncle, and who uttered this verse as she drifted away:

> If evyr maden's malysone dyd licht upon drie lande,
> Let nocht be funde on Forvy's Glebe, but thistle, benk and sand.

On the western coast of Europe, from the Pyrenees to the Baltic, blown sand advances landward at the rate of three to twenty-four feet annually, overwhelming houses and fertile fields in its advance. On the shores of Lake Michigan, in North America, the sand has covered swamps and forests, and even low hills.

The Entombed Cities of Antiquity and their Concealed History

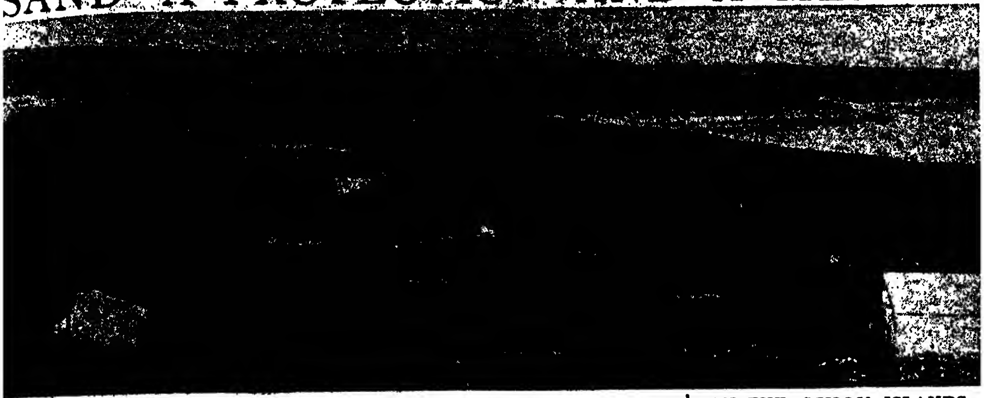
But not only along the seashore are the effects of sand carried by wind noticeable. The same things happen in the great deserts of the world, such as in Sahara, the centre of Asia, and the interior of Arabia. In Mesopotamia and Central Asia many ancient cities lie entombed in sand, carried by wind from the desert, such as the famous cities of Nineveh and Babylon, Ur, and Erech, and innumerable towns have been buried on the west side of the Nile between the Temple of Jupiter Ammon and Nubia. It is likely that the chief discoveries of the future which will throw light on the disconnected history of the peoples of the East lie hidden at this moment under the sands from Mesopotamian and Arabian deserts.

THE DESERT TRAVELLERS WATCH THE PERIL OF THE DUST GO BY

Dust, raised in storms, flung high from volcanoes, scoured incessantly from the dry earth by gusty winds, plays a part in hygiene and in optics that is only now beginning to be understood. This fine desert scene is reproduced from M. L. Graninger's picture "Escaped from the Peril."

By permission of Robert Arnot, publisher in Paris and Vienna

SAND—A PROTECTION AND A MENACE



BLOWN SAND PROTECTING LOW-LYING GROUND AT ST. MARTIN'S IN THE SCILLY ISLANDS

SAND-DUNES THAT ACT AS A DEFENCE AGAINST THE SEA, AND ALSO SHIELD CULTIVATED LAN

SAND-DUNES INVADING THE LAND AND FORCING BACK CULTIVATION ON THE CORNISH COA

SILENT WORKING OF THE MOULDING MIND

That Life at its inmost core is Mind is suggested in this tense figure concentrated on one thougl

From the great sculpture "The Thinker," by Augustin Rodin.

ONENESS OF LIFE AND MIND

Mind the Underlying Motive-Force of the Living World Aiming to Transcend Itself

LOVE AND INTELLIGENCE HAND IN HAND

No theory of evolution can be called anything but a makeshift that does not offer us a positive explanation of the greatest triumph of evolution. That is the intellectual and moral nature of man. Though natural selection, mercilessly destroying incapacity to live, has had to be reckoned with at every stage in this process, we see clearly that it has not constructed either intelligence or love, though it may have first tolerated and later confirmed them. We require something more, if we are to bring the characteristic facts of man into the evolutionary scheme at all. So beggarly has always been the merely mechanical and negative theory of natural selection to explain the evolution of man's higher nature that, from the first, Dr. Alfred Russel Wallace, the co-discoverer with Darwin of the principle of selection, has always denied that this principle would account for these greatest triumphs of evolution. He has invoked a non-scientific, supernatural explanation for the origin of the *psyche* of man; and though we cannot accept that explanation here, and do not find it necessary or desirable, we should note that one of the original discoverers of natural selection has always proclaimed its hopeless inadequacy to explain the greatest facts of evolution.

Those greatest facts are clearly two, though they are two in one, and we shall consider them separately in the light of the long foregoing discussion, which has given us the successive contributions to the theory of evolution, from Lamarck, at the beginning of the nineteenth century, to Bergson, at the beginning of the twentieth. The two supreme products of evolution, hitherto, for which we have to account, are intelligence and love. These we see in their highest form in man, and our explanation must include man. But, after all, we are evolutionists; we have studied the world of life in general, and we see clear evidence of intelligence and of love among the lower animals. Man is doubtless unique and unparalleled, but his characteristics, though so great, are not *new* in the history of life, and do not require us, all of a sudden, to abandon any theory which will carry us as far as from, say, the amœba to the ape.

We have already seen that the line of intelligence is one of the three great lines along which life has evolved. It has become most evident with the evolution of the particular type of nervous system which is characteristic of vertebrates, and which has been rising in complexity and in actual bulk, from the earliest fishes up to man. The older, materialist theory of evolution teaches that intelligence, and even consciousness, of which intelligence is an aspect, appears with the appearance of the brain, and as a consequence of it. Random variations in the protoplasm of germ-cells, controlled by natural selection, make the brain; and when this structure has been formed, consciousness and intelligence begin to appear. But all that, we see, is putting the cart before the horse. Consciousness and intelligence, in a primitive form, are older than the nervous system of man, older than the nervous system of the fish, older even than any nervous system. They are part of the original nature of Life. They can be found in the lowest living organisms; and their appearance, at their height, in man, is a progressive and purposive consequence of their inexhaustible "thrust," from the beginning of life at all.

Evidently animal psychology, popularly supposed to be the somewhat imaginative hobby of leisurely and elderly gentlemen who write to the "Spectator," becomes a matter of life and death to the evolutionist who has come so far. Evidence of anything

that can be called intelligence, in dog or cat or bird, is not merely a curiosity or a tale for an idle moment, but a fact for which science and philosophy are breathlessly waiting. We are not going to argue the point here. Overwhelming evidence of animal intelligence has already been presented in the section devoted to animal life, and that fact is a definite *datum* for evolution to interpret. It exalts the animal world, without in any degree debasing man, except for those strange people who cannot realise the idea of absolute worth, and only count honour or capacity worthy by contrast with lesser things.

Consciousness, otherwise Mind, to be Found in the Lowest Forms of Life

But the proof of intelligence in ape or cat or dog does not suffice, for all of these are high in the rank of vertebrates, and possess a definite and complicated brain. The materialist theory, according to which consciousness is only a kind of phosphorescence that spreads around a brain of a certain stage of development, may still be arguable from the dog as from man. It is necessary for us to look very closely at the lowest forms of life, or, at any rate, at forms in which no nervous system whatever, let alone a brain, is to be found. Of course, intelligence and consciousness of any kind will need more looking for here, and will escape casual observation, for we cannot expect them to appear so saliently as when they have fashioned, or Life has fashioned, the special structure through which they appear so well; but the evidence is to be had, and its importance for science and philosophy can obviously not be overestimated.

The Existence of Feeling and Response in the Humblest Forms of Life

We can afford to go as low even as the amœba and the humblest infusoria. Of course, they obey physico-chemical laws. So does man, and the fact is nothing to the point. But when we examine them closely, we find it impossible to explain their movements in physico-chemical terms alone. The casual observer is content with such an explanation, but the various men of science who have really devoted themselves to this study, from Maupas, in 1883, to Jennings, in the last few years, have clearly proved that in these humblest manifestations of life there is "an effective psychological activity." These creatures exhibit "behaviour." They feel and respond—a notable fact in itself—so long as they are alive, but they do more: they learn, and choose, and refuse, and adapt themselves. We have already seen that life has taken a different course in the vegetable world, but it is to be remembered that the humblest plants exhibit these psychological traits also, and that in higher forms there is clear evidence of something psychical, even though it be imprisoned in its wall of cellulose. Lord Morley has referred to Wordsworth's famous declaration of his faith that "every flower enjoys the air it breathes" as a "charming poetic fancy and no more, and it is idle to pretend to see in it the foundation of a system of philosophy." We are not so sure to-day that Wordsworth did not express, doubtless with poetic licence, a truth which *is* essential to our system of philosophy. But this is not the place in which to do more than simply state the existence of psychical traits in the vegetable world.

With that statement the argument is complete that mind and life are fundamentally co-extensive. Where there is life there is mind; and the phenomena of mind, at their highest and rarest, are natural and vital, and are evolutionally connected with and continuous with the facts of life in its humblest forms.

Life and Mind are One Through the Whole Scale of Being

These—need it be insisted?—are tremendous statements, alike for science and philosophy, and are a subject for volumes. Our present concern with them is their bearing on our theory of evolution. The proposition that life and mind are really one; that the function we call mind precedes and creates for itself the structure we call body, including the nervous system and the brain, even of man, is the *only proposition* on which we can base a theory of evolution that is worth a glance. The evidence for it has here been summarily stated; and the reader who would inquire into it further must consult Bergson's "Creative Evolution," and Dr. McDougall's remarkable new volume on "Mind and Body." Here let us realise how valuable the perception of this truth is, and we cannot do so better than by looking at the alternatives.

One, already alluded to, is that, in short, of "drawing the line" at man. Thinkers of this school can accept the idea of evolution in plants without reserve, and they can accept it in animals as far as man. When they come to man they feel bound to distinguish. As regards his body, they have no doubt. His relation to the bodies of animals is duly discussed elsewhere in this

work, and is so evident that they do not gainsay it. They may not have, none of us may have, an adequate theory of the manner in which evolution occurs, but that does not matter; the theory that would take us as far as the ape will certainly take us as far as the body of man.

But these thinkers cannot accept the view that the *psyche* of man is also an evolutionary product. When mind becomes so glorious, it seems wholly separate and original to them, and they feel compelled to say that this highest part of man is a "special creation." The difficulty of this view is extreme if we remember that these thinkers recognise the relation between mind and brain, and admit the brain to be an evolutionary product. That is to call the function a special creation, and the structure a product of evolution. Such a doctrine is plainly desperate, derived from the feeling that science must be abandoned, and logic, too, when we reach this point. But that would be a lamentable conclusion if it were true, and to accept it would be to abandon science and discredit it, not only here but everywhere. The truth that mind and life are one, and have thus evolved together, delivers us from this hopeless *impasse*.

A PAIR OF AMŒBÆ ATTACKING DIATOMS

Amœbæ have free motion in water; the lower amœba is seen to have enveloped several diatoms in its substance. This picture is magnified 20,000 times.

No less does it deliver us from the violent contradiction of our own creed which is evolved in asserting that evolution goes on and on, unrolling new and more complicated forms of one thing, living matter, until, all of a sudden, there appears a staggering novelty, with no history, called the intelligence of man. The evolutionist cannot deny or discredit that intelligence, for that is to discredit his own theory. And if he says that it suddenly comes without a history, he is also denying his own theory that evolution is universal, and that there are no exceptions to it. Thus the evolutionist, of all men, requires to see the truth that mind and life are really one, for that doctrine alone will enable him to make and complete a statement of evolution at all. Without it he must leave out the *psyche* of man; and who would care a rap for his theory then?

All this is great gain; inestimable gain, if we recall what we were asked to believe, by representative evolutionists, in the nineteenth century. It allows us to assert, without the monstrous self-contradiction of materialistic evolution, that the *psyche* of man is an evolutionary product. It makes evolution an infinitely more glorious and more important thing than if it were merely the evolution of bodies. It raises incalculably the study of the behaviour of animals and plants, of every grade, and in all possible circumstances, and it exalts biology, or the study of life, as mind alone can exalt anything. In the Universe, said Sir William Hamilton, there is nothing great but man, and in man there is nothing great but mind. We feel compelled to agree, whoever we be; but now we see that the study of life, even in its rudiments, and even in its mere physical mechanism, *is* the study of mind, which becomes at last, and which illuminates beyond words, the study of the mind of man.

But this transcendent gain of ours, as compared with the generation of evolutionists before us, involves also a loss, if to lose the worthless is loss. For, once we have grasped the relation of mind to life, once we have realised what evolution therefore asserts—which is the evolution of the minds of Shakespeare and Socrates and Newton from the amœba and its feeble perceptions—we find that we have lost our comfortable assurance that we had an efficient theory of evolution. The automatic process whereby forms which cannot

survive do not survive, which we call "natural selection," and which, even ten years ago, was thought to be "an efficient cause of evolution," is seen in the full measure of its irrelevance and inadequacy. There have been many bad dramatists, before and since Shakespeare. Their dramas are dead, and his alive. This is natural selection in a typical form. And we have hitherto talked of evolution at large as if this natural rejection of bad dramas had written "Hamlet"! We should be ashamed of ourselves.

How Mind is the Underlying Motive Force of the Life of the World

Certainly we have lost what was not worth losing, and now we realise that we are very much in need. We still have to explain, even only to name, the motive force of evolution, but, once our need is known, it can be met. The motive force of evolution is psychical. It is the impetus of Life-that-will-not-be-denied, which "sweeps through the dull, dense world," and which we feel and exhibit and know at first-hand in ourselves whenever we really are ourselves. This is to assert that, in our century, we are compelled to state the theory of evolution in terms of mind instead of matter, and that the very theory which was supposed to be, and was stated as if it were, materialistic becomes the best warrant for the great doctrine, held by the supreme thinkers of all ages, that Mind is the underlying and motive force of the living world.

The original psychical impetus of Life expresses itself, we have already seen, in various evolutionary forms, of which intelligence is one. Here we need say no more of it in itself, but must pass on to note its historical relation to the other great triumph of evolution, which is love, the essential constituent of the moral nature of man and, in humbler yet often noble forms, of many of the lower animals.

Why Mind has been Excluded as a Section from this Work

But before we observe the peculiarly dependent character of intelligence, let it be noted how the foregoing argument justifies, from the standpoint of science, the omission of any section called Mind from this work. The critical reader will observe that nowhere in these pages has mind been denied or dismissed as an unreality or as outside the scope of science; nor could anyone deny that there exists already a great science of the mind, called psychology. It has been formally laid down in the section on the "Universe"—a term which should surely include everything—that Mind is at least one of the ultimate realities of the Universe, and yet no attempt has been made to deal with it there, and it was even pointed out that in studying, for instance, the behaviour of the heavenly bodies we must deny any interference with them by Mind, and must exclude Mind from those pages. Yet we have no section on this great theme. The reason will now be apparent. Mind and life are not things apart, much less are mind and man, the highest form of life, things apart. Mind needs no special section, because the sections Life and Man are bound up with it, because life is ultimately psychical, and because no discussion of man could be other than dishonouring to the subject and the writer which did not regard his mind as the essential part of him—a proposition which now sounds all the juster when we have learnt that mind is the essential part of all life.

Only by the Evolution of Love is the Evolution of Intelligence Possible

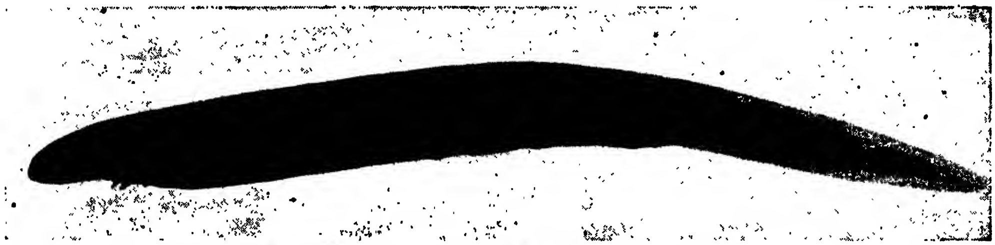
The special problem now before us is the evolution of the intellect; and the proposition which we shall lay down is that the evolution of intelligence, culminating in its highest form, the intellect of man, necessarily and absolutely depends upon the simultaneous, or rather the prior, evolution of love. These two, then, which we have called the triumphs of evolution, and which reach their highest in the mental and moral nature of man, are to be proved interdependent, and their association not an accident, still less a misfortune, but a necessity. The sum of the matter is that only by the evolution of love is the evolution of intelligence possible; and this statement must be weighed against that theory of evolution, unjustifiably based upon Darwin's theory of natural selection, which asserts that evolution depends upon a brutal struggle in which charity, sympathy, mercy, forbearance, pity, are weakness, and lead to degeneration. This truly abominable theory, the foulest thing ever yet conceived by the mind of man, is the direct opposite of the truth, as expressed partly by natural selection and chiefly by the new theory of evolution to which the last chapter of this section was devoted. The denial of this horrible doctrine is partly due to Professor Henry Drummond, Dr. Sutherland, and others; the present writer endeavoured to carry it further several years ago, and here he will reproduce that argument, appending

thereto a notable passage from Bergson, written at a later date, which confirms the argument on the new grounds.

Let us begin by noting that, of course, there never was any excuse for the perversion of Darwin's theory for which Nietzsche is chiefly responsible, and which has been renewed, since the death of Sir Francis Galton, by certain advocates of eugenics who wish to humanise man by brutalising him. On the Darwinian theory itself, love and pity are products of natural selection, and are therefore justified, and must be assumed to have a value for and in evolution. They are as demonstrably in the ascendant, from the humblest vertebrates up to man, as the brain is, and can no more be called degenerations than the brain can. To turn round and condemn them in the name of evolution is therefore to deny evolution itself. But let us look at the facts: they will display the evolution of something which can only be called *organic morality*.

thus needs the greater display of what we have called organic morality on the part of its parents. Thus organic evolution, reproductive evolution, and moral evolution are interdependent, along the great line which leads through the vertebrates to man—the only open road of life.

The highest vertebrates, the mammalia, of which man is the last and highest, surpass all the past. In the mammalian mother organic morality has advanced further than in any of her predecessors, for she possesses bodily organs solely designed for the benefit of others—the unique distinction of the mammalian breast. As the mammalia ascend, the periods of gestation or expectant motherhood, and of lactation or nursing, increase, reaching their longest and most exacting in our own species. But the more the mother gives, the greater her devotion and labour and faithfulness, unconscious and conscious, "organic" and super-organic, the more helpless is her off-



THE LANCELET, A PRIMITIVE VERTEBRATE THAT HAS NOT ACQUIRED A DISTINCT BRAIN

The lancelet, or amphioxus, a primitive fish-like animal about one-and-a-half inches long, is characterised by the absence of a distinct head or brain. In this photograph the spinal column is seen black, and below it the dark coloured notochord, its nerve centre, running the length of its body. This photograph and that on page 1639 are by Mr. J. J. Ward

We are here concerned with that particular line of evolution which yields us the vertebrates, intelligence, and man. The case of the line which yields us instinct, through the invertebrates called insects, is different, for the evident reason that the instinctive animal needs no help nor education, but is born perfect as far as it goes. Let us note these facts for comparison when we come to look at intelligence. Along our line the facts, in brief, are that from the earliest fishes (to begin no lower) up to ourselves, the reproductive act increasingly displays a moral aspect. Reproduction, the production and care of other individuals, becomes the chief opportunity of altruism, which is other-ism. The reproductive function always tends to become more difficult and exacting with the increasing worth of the individual produced. The new individual is born, not more and more efficient and competent as life ascends, but *less so*—the supreme paradox of the living world. It

spring, and the longer so. Contrast the young reptile, or even the chick, with the kid, and the kitten, born blind, lame, helpless. But then compare kid or kitten with a baby, say at six weeks old. The animals can now feed themselves as they run about. The child is still helpless. It needs incessant care in order to keep it alive. It is unarmed, naked, defenceless; a poor match for the kid of its own age. Yet man survives. This creature, not one specimen of which would survive its birth for twenty-four hours if left to itself, becomes the dominant species of the earth, the highest form of life we know.

Natural selection is by no means mocked. The baby has, or, rather, its mother has for it, some factor of "survival-value" which entitles it to survive. Its name is love. The higher the race, the more helpless are the young at birth, the longer do they need parental care, and the more assiduous must that care be. This parental care furnishes

the baby, for the time, with the weapons of its success in the struggle for existence. It is uniquely deprived of other factors of survival-value, being at its birth the most helpless of all the forms which Life has ever produced; but parental care constitutes for it a factor of survival which more than compensates for the absence of all the rest. We may and must freely grant that natural selection is impersonal and non-moral. It has no bias in favour of beauty of body or the "beauty of holiness." It rejects whatever cannot live—altruism in excess or bacteria that are not poisonous enough. It selects or tolerates whatever can live, without a trace of moral bias. But it is concerned to select the fittest, and thus, in man, it selects the most moral.

Natural Selection Selects Love and Morality Because they Serve Life

Morality and love, then, are not an absurd invention of the priests; sympathy is not "the morality of slaves," invented by an enslaved people under the name of Christianity, as Nietzsche declared; nor does it oppose the operation of natural selection, which Nietzsche and the neo-Nietzschean eugenists declare to be the only means of giving us the Superman. The statement of natural history is that *natural selection selects morality.* Love is older than mankind, far older than any existing Church or creed, and will outlast, because it shall yet transform, them all.

The enemies of love have appealed to natural selection; and to natural selection they shall go. Even this mechanical, negative, material, lifeless factor of the evolution of life returns a verdict in favour of morality, as the emergence and triumph of love prove. But we have already learnt that natural selection creates nothing, whatever it may select, or, rather, whatever it may tolerate. We still require, therefore, a positive explanation of the emergence of love. It can, of course, only be the explanation of Shelley and Spencer and Bergson—the explanation here given. The evolution of love and of intelligence is explained because love and intelligence serve life, or because they are native in the primal essence of life.

Life a Progress—Each Generation Leaning Over the Next in Love

The aim of life is to live and to transcend itself. Hence, as we have learnt, its invention of death in the service of higher and fuller life to come. Life is a progress and a movement. In its course it makes individuals, whom we think of as *things*, though each of them is really part of a progress. "At times, however," says Bergson, "in a fleeting vision, the invisible breath that bears them is materialised before our eyes. We have this sudden illumination before certain forms of maternal love, so striking and in most animals so touching, observable even in the solicitude of the plant for its seed. This love, in which some have seen the mystery of life, may possibly deliver us life's secret. It shows us each generation leaning over the generation that shall follow. It allows us a glimpse of the fact that the living being is, above all, a thoroughfare, and that the essence of life is in the movement by which life is transmitted."

Finally, we have to justify the assertion that intellect and love, which seem so different, are interdependent, and in so doing to explain the paradox that the most competent race is born the most helpless. This has been worked out years ago by Dr. McDougall, by the present writer in his paper to the second Infant Mortality Conference, and in masterly and surpassing fashion by Bergson. In general, while instinct cannot learn, it need not, for it is born perfect within its limits, which it will never transcend. *Intelligence has everything to learn, but it can learn everything.*

Because Intelligence Can Learn Everything it has Everything to Learn

An intelligent being bears within himself the means to transcend his own nature, as man is always proving. To intelligence, and to intelligence alone of the three directions in which life has evolved, the road is open to the infinite. Instinct is lost in novel circumstances, and can answer no questions. Intelligence can adapt itself to new circumstances, answer novel questions, and, in its greatest moments, can create new circumstances and ask supreme questions, even though it cannot answer them all as yet.

But just because it can learn everything, it has everything to learn. Hence the key to the paradox, that the more intelligent a race the more helpless is it in infancy. To be born competent is to be born incompetent for progress. The infant is helpless because of the nature of the endowment with which it will some day help itself to the earth and the fulness thereof. And because it must be helpless, it must have the care of parenthood or foster-parenthood.

Our long argument thus culminates in certain great propositions which may here be reasserted, as in the form given them by the writer eight years ago. Not only is the Nietzschean doctrine that morality is a

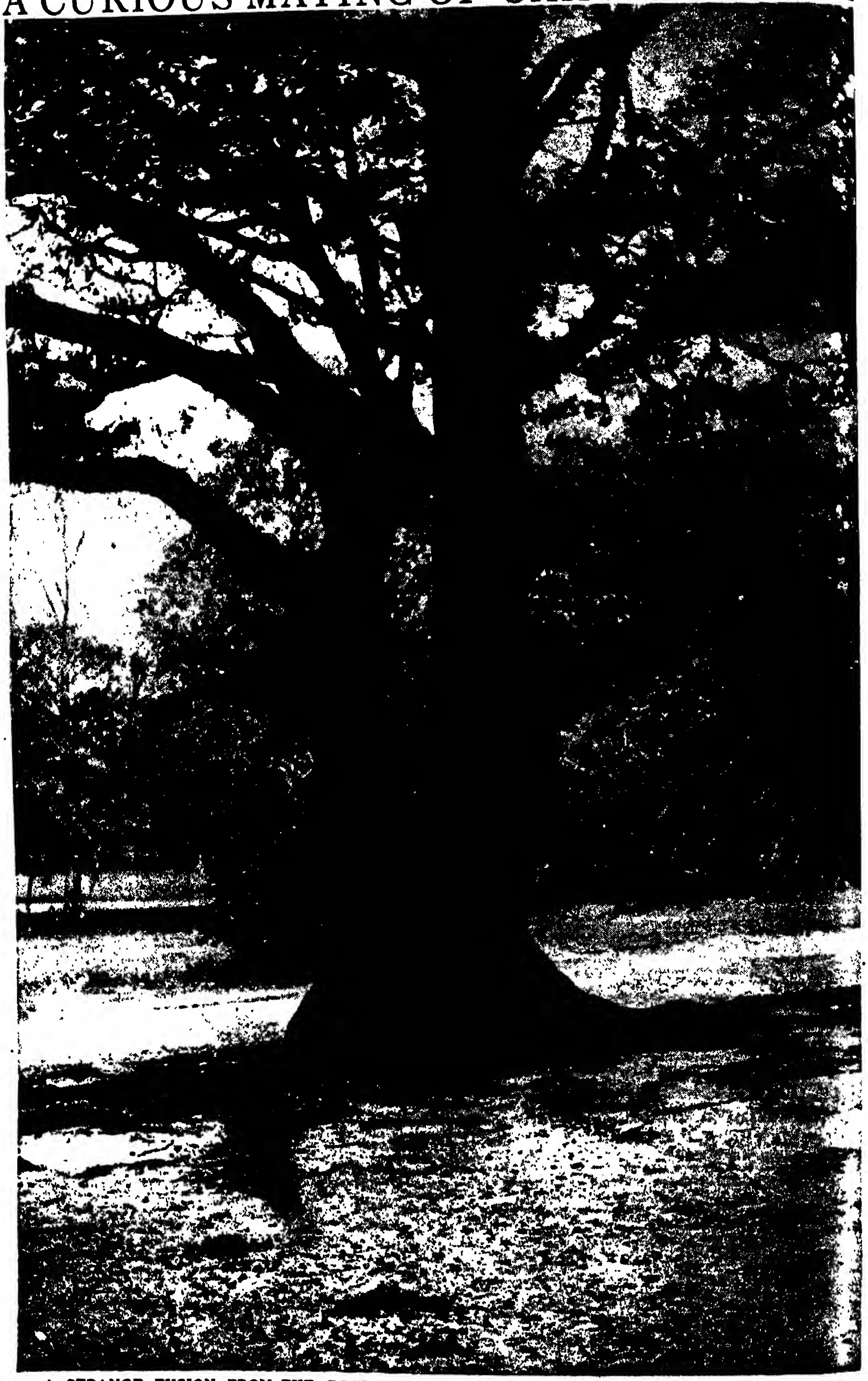
product of man in slavery untrue, but the truth is that man is the highest product of morality. The law of Nature is: *No love, no intellect; no morals, no man.* The triumphs of man are the triumphs of woman. Baby-saving is intellect-making. The unique helplessness of the human infant is due to his unique departure from the instinctive endowment of life, skilled but rigid; and the unique prolongation of his dependence is due to the unique extent to which intelligence develops in him. Indeed, to the end he is dependent upon the generations before him. Their skill and sacrifice and care have endowed him with the conditions which make his life as an intelligent being possible; his ancestors watch over the bed of the man in his glorious prime, and guide and guard his day. This is the forward purpose of life, still justifying itself. Sacrifice, devotion, love, alike for those we have in our arms, and for the future which we shall never see: these are the very conditions of the life of an intelligent species, reminding us of the fine sentence which contains the essential conclusion of Herbert Spencer's philosophy: "A transfigured sentiment of parenthood, which regards with solicitude not child and grandchild only, but the generations to come hereafter, fathers of the future, creating and providing for their remote children."

It would seem, then, that the gospel of force is based upon shameful ignorance of the facts of biology. These facts teach us that altruism has been an indispensable factor not merely in the ennobling of human life but in its actual production. They further teach us that morality is no artificial product, but an inalienable possession of humanity, older than all the Churches, much older than human thought. Thus, though "Nature, red in tooth and claw;" may appear indifferent to good and evil, her sun shining alike on the just and the unjust, yet every new baby teaches us that love is a cosmic product of which humanity itself is not the author but the fruit; and that, therefore, Emerson was justified when he said that "the universe is moral."

THE LOVE THAT HAS MADE THE EVOLUTION OF INTELLIGENCE POSSIBLE
From the painting "The New Arrival," by Mr. Walter Langley, reproduced by permission of Messrs. A. Vivian Mansell & Co.

The untutored daily observation of all men in all times, and the theory of evolution, which is the highest product of the tutored observation of all times, alike teach us that altruism is an inherent factor in human life, older than all religious and ethical systems, and destined to outlive not, indeed, Truth, which "fails not, but her outward forms that bear the longest date."

A CURIOUS MATING OF OAK AND BEECH



A STRANGE FUSION FROM THE ROOTS OF AN OAK AND A BEECH IN THE NEW FOREST

The photographs on these pages are by Messrs. Hinkins and Son and Mr. J. T. Ward

PROPAGATION OF PLANTS

Artificial Reproduction by Cutting and Layering, Budding and Grafting. Problems of Hybridisation

WHERE PLANT & ANIMAL GROWTH DIFFER

We have recently been considering to what an extraordinary extent it is possible for man to interfere in the normal life of plants and trees for purposes of his own in the direction of producing trees of various sizes and shapes, and fruits of special quality. We have referred to the methods by which these processes are carried out as the "surgery" of plants; and we have already pointed out that the plant surgeon actually goes so far as to create species of a type which he himself has mentally conceived. This he does by the process of hybridising. But we have by no means finished with the science of plant surgery. There are yet other possibilities to be considered.

It will be recognised, of course, that all these processes, directed to the production of special types of plants, depend really upon the phenomenon of reproduction in plants; and it may be well here to emphasise that this physiological function of reproduction, by means of which plants have the power of producing new individuals, occurs in two perfectly distinct ways in the vegetable kingdom.

We have, for example, reproduction by sexual methods in plants just as in animals, methods which are known as fertilisation, and concerning which we shall have a good deal to say at a later stage. At the same time, reproduction in plants may be carried out by what is termed the *vegetative* method, and it is to this process that we are at present directing our attention.

Vegetative reproduction in plants is a phenomenon which may be seen in quite a number of different phases, and it may occur either naturally or by artificial interference on the part of man. An example of natural vegetative reproduction and multiplication is that seen in the potato plant, in which the underground roots, which proceed from the parent plant, grow into thickened and swollen portions at their extremities—the potato or tuber. In ordinary agriculture this is dug up for food; but if it be left in the ground when the haulm dies down, every tuber or potato in the following year will, by the process of vegetative reproduction, spring up as a new plant. This is quite a common process with plants having underground roots.

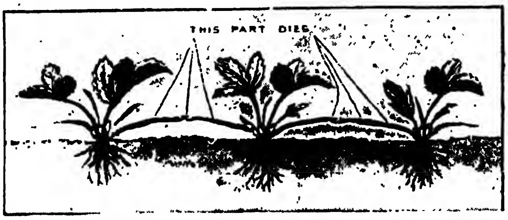
Another instance of this process of reproduction is that seen in the strawberry. A strawberry plant, left to itself, produces a number of "runners," which spread over the ground in various directions from the central plant and take root at intervals. From each node at which the runner takes root a growth of a new individual plant arises, and the separation occurs by gradual decay of the tissue of the runner, which originally united it to the parent plant.

Many other instances of similar vegetative reproduction are seen amongst bulbous plants.

It was doubtless originally from the observation of this natural process that the primitive gardener conceived the idea of imitating it artificially. If plants could give rise to new individuals by rooting little pieces of themselves in this way, why should not man take such portions of plants as he wished and make new individuals from these? True, it is a somewhat extraordinary thought that a small portion of a plant cut off from its parent stem and placed in the ground should have the power of producing a complete individual with all its parts, but it is, nevertheless, true. This is one of the marvels of plant life as distinct from that of the life of higher animals.

It is a simple fact that a piece of a root, a portion of a stem, or—still more wonderful

—even a portion of a leaf of some plants, separated from the parent's growth and put into an environment which offers suitable nutrition and protection, are actually capable of producing roots for themselves and ultimately complete individual plants, having all the characters of the parent plant from which they were taken. This primitive discovery, probably made when man carelessly stuck a stick into the ground and left it there, and which was afterwards found to have taken root, doubtless led very soon to the method of propagation of plants by means of cuttings. Observation of other plants would lead to artificial reproduction by means of *layers* as well as cuttings, and these in time to the more elaborate procedure of budding and grafting.



VEGETATIVE REPRODUCTION—SELF-LAYERING STRAWBERRY RUNNERS

In the process of vegetative reproduction from cuttings, any portion of the plant, be it leaf, branch, or root, may be used, though not with equal success in all plants. Not only so, but—extraordinary as it seems—it actually does not matter which end of the cutting is planted in the earth—it will take root either way. The greatest development of roots, however, always results when the end of the cutting nearest to the earth in the parent plant is the part that is planted.

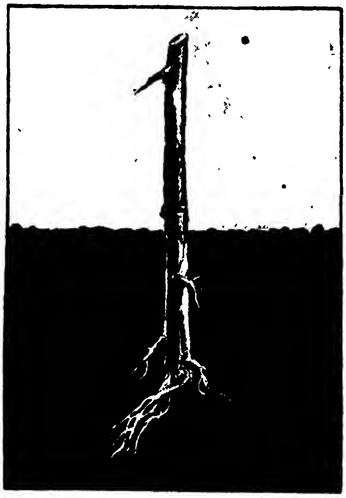
VEGETATIVE REPRODUCTION BELOW THE SOIL
The lily-of-the-valley differs from the strawberry by developing its branches underground, as here shown.

As examples of plants which may be propagated from root cuttings we may mention pelargoniums, while an example of propagation from leaf cuttings is to be found in the well-known begonia. In the latter case it is only necessary to place the leaf, or a portion of it, on moist soil in a suitable temperature, and Nature will do the rest. More common, however, is it to select young shoots for propagation by cuttings; and these are cut off just below a node, as it is at this point that the new roots appear. Many of our domestic plants are readily and easily propagated by this method, amongst the most notable, perhaps, being currants and gooseberries. The cutting is usually from eight to ten inches in length, and is taken from the parent plant at the end of a season's growth, when the leaves have fallen off. The buds on the cutting are rubbed off where it is to be inserted under the ground.

Vegetative reproduction by means of layers is done by fixing a portion of a young shoot into the earth by an artificial pin of some kind. The shoot is simply bent down and forced underground to such an extent that it is well covered. In due time the underground portion gives off roots; and when that has happened the bent portion above the level of the soil may be divided with the knife, thus severing any connection with the parent plant. Imperfect division of the portion bent underground is also practised to prevent the flow of sap back from the free portion of the shoot. This helps in the formation of new roots. Naturally, it is easier to strike a new plant by means of layering than it is by cuttings, because in the layering process the connection between the old plant and the one that is to be produced can be maintained as long as necessary. As a matter of fact, this process is largely used when it is wanted to grow apple, pear, and other fruit stocks quickly, these being used afterwards in the further process of grafting and budding, to which we must now pay attention.

Budding and grafting may be regarded as the last word in the surgery of plants, being operations which demand the greatest skill and judgment, both in selection of the tissue to be used and in the technique of the procedure itself. In the case of budding, a bud is cut away from one plant and inserted into the stem or stock of an entirely different one; whereas in grafting, a piece of a shoot which bears upon it several buds is transferred to an entirely new stock, and by a somewhat different method. The

shoot itself is spoken of as the graft, or scion. In both cases, however, the bud and the scion become so fused as to live the life of one individual plant, no matter how diverse they were originally. This is rendered possible because the roots of the stock gather the nutriment, such as water and its contained ingredients, and these are passed up the stem and into the tissue of the graft by means of the process of osmosis; so that we have graft and stem living one life and deriving their nourishment from a common root, which, nevertheless, retains its own special peculiarities. So that the extraordinary phenomenon may be observed of entirely different kinds, or rather qualities, of fruit growing from a single branch—one from the graft with its qualities, the other from the original stem with its qualities. Indeed, it is quite possible, and it is frequently done, to have quite a number of different kinds of a fruit grafted on to one common stock. These are curiosities of grafting.



FORMATION OF NEW ROOTS FROM A CUTTING

The various processes by means of which branches or buds of one plant are transferred to the stock of another, so as to induce an organic union between the two, are sometimes spoken of as "ennobling," and this term includes what we have described in the terms of budding and grafting. It was probably originally suggested by the observation of the fact that true parasitism occurs amongst plants, even amongst woody plants, as we shall see in a later chapter. Doubtless most of our readers have at one time or other observed also two branches of a tree, or two branches from separate trees, which have happened to grow in such a direction that they cross each other at an angle and come into contact. When this is the case, in course of time they grow together and physically unite. Such a natural occurrence would suggest that a similar operation might be artificially performed with great variety. The plant or tree from which the bud or graft is taken is usually of a higher type or quality, from some point of view or other, than that of the stock upon which it is to be budded or grafted. It is either from a valuable kind of fruit-tree, or a peculiarly beautiful ornamental shrub, which the gardener desires to perpetuate and improve, or to add to or multiply the specimens in his collection. He chooses his stock from a strong, healthy growth of an individual plant belonging to the same class as the bud or graft he is about to transfer, but from a wilder species. It is, therefore, often spoken of as the "wild stock," in opposition to the term "noble scion," applied to the bud or graft. That is why the whole process is termed "ennobling"; it raises the character and type of the growth from the stock.

Although there is a very wide measure of success in these processes, still there are limits to its possibilities. All shrubs and all trees cannot be made to unite with each other just as one pleases. In order to have any certainty of obtaining a successful result, the graft or bud and the wild stock must have racial affinities more or less close; that is to say, the process is most certain and most successful when carried out between members of the same family or genus. Hence we find that it is quite easy to graft plums, apricots, almonds, and peaches one upon the other, as well as pears, apples, quinces, and medlars, all these plants being closely allied in origin. But statements that peaches can be successfully grafted upon willow stocks, or that the Siberian crab has sprung from the grafting of branches of the pear upon the willow, and other similar stories, may be relegated to the realms of fiction.

THE METHOD OF LAYERING A CARNATION

As would be expected from the fact that the juices in the wood of the stock are conducted directly into the tissues of the

grafted portion, there is a certain amount of alteration in the character of the two portions subsequently. The pear grafted upon the quince, or other stock, always remains a pear, and retains its own special characters—those for which it is being grown. It is, nevertheless, true that the pear-tree resulting is altered in certain minor directions, and, indeed, that is the whole object in the process. The fruit which results may become larger and of better quality than that from which the graft was taken, or it may appear and ripen earlier or later in the season, as the case may be. The shape and habit of the whole growth may vary from the original, and all these, and other similar variations, may be ascribed to the influence of the special nutrition supplied to the graft through and by means of the tissues of the stock. Exactly how these variations are brought about is not quite understood; that is to say, why the branch which springs from the graft should behave differently from others is not quite clear, but it is probably connected with some interference with the process of cell nutrition at the exact point of union of graft and stock.

HOW NATURE HEALS A TREE'S WOUNDS

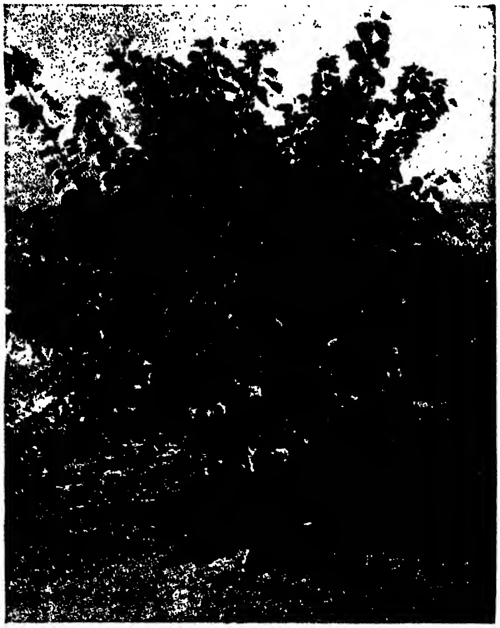
Whatever be the exact cause, the fact remains that if a tree of a fruit-bearing type be grafted on to a wild stock from the same family, better quality and larger quantities of fruit result than if the tree be grown from its own roots.

Coming now to the actual details in the process of budding, it may be noted that there are a good number of different ways both of preparing the buds for transfer and for treating the scions to which the buds are to be transferred. We may take one of the most common procedures as an illustration, as the principles of these methods are the same. A very usual operation amongst those whose business it is to deal with fruit-trees is that known as shield-budding, which is done best in the months of July or August, since at that time the bark of the stock is easily separated from the wood underneath. This is essential, because it is into the cavity made by this separation that the bud must be inserted. The buds themselves, which are wood-buds, are taken from the fresh shoots of that year's growth, and should be neither too young nor too old. This is provided for by taking the bud from about half way up the shoot—that is, where the wood is about half ripe.

The operator having selected the bud which he is about to use, cuts it out of the young shoot, along with a piece of the bark, this piece being in the shape of a shield, hence the term "shield-bud." The incision made in doing this is sufficiently deep into the shoot to carry away with it a very small piece of the wood, and this is carefully pulled off from the bark, and thrown away. This is perhaps the most delicate part of the whole business, because in pulling away this portion of wood one is apt to tear with it the axil of the bud itself. When this is done there appears a hollow depression, and the bud is useless. Having, however, successfully avoided this danger, the leaf in the axil of which the bud is growing is also cut off, and the bud is now ready for inserting into the bark of the stock.

The cut in the stock is made in the shape of the letter "T," and the bark raised a little on either side of the incision. The bud and its shield are then inserted into the aperture so produced, and the folds of the bark allowed to fall back over the sides of the shield, which they thus maintain in position. The whole thing is then firmly secured either with raffia or some other binding material, leaving only the tip of the bud exposed. If the bud has not been damaged during this operation it will be firmly united and the wound healed in the course of two or three weeks, at which time the bandage or binding can be safely removed. If there is any reason to think that the growth is not yet thoroughly established it may be left for a month. The only other point to which attention is necessary is to see that no other growth is allowed to occur from the stock that season, except the bud

A peach-tree, one year's growth from a bud.

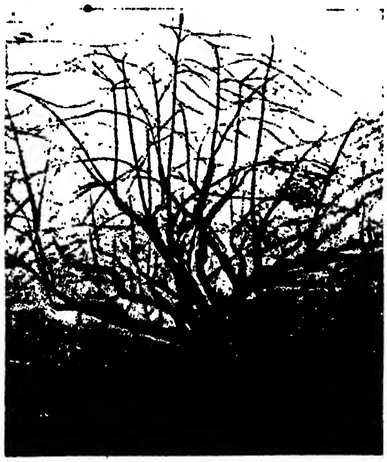


An apricot-tree, three years' growth from a bud.

RESULTS OBTAINED FROM SINGLE BUDS ON A NEW ZEALAND EXPERIMENTAL FRUIT FARM

In other words, the object is to direct all he nutrition of the stock to the site of the iew growth.

Whenever the surgeon, be he animal or ılant surgeon, makes an incision into the issues of his patient, this is followed in due ime by what is known as the process of iealing. In animal tissues he ultimate result of this rocess is familiar to all of is in what we know as a car, and the process of iealing up in a surgery of every wound in plants s very similar, and somewhat analogous. Here, oo, we have a scar produced, such as may be een on the boughs of ılmost any tree, and this iealing tissue, or "callus," s formed by the cambium of the stock and the cambium of the transplanted oud, these two becoming ntimately and organically ınited.



A TOP-GRAFTED APPLE-TREE

Coming next to the actual operation of grafting, it may be remembered that the design here is exactly the same as that in the process of budding, namely, the ennobling of a portion of one plant by inducing it to grow by means of the nourishment supplied to it by another. As in the case of budding, an original stock, either wild or otherwise, is required, and this has to be treated in such a way that the cambium layer of the vigorously growing stock can be brought into intimate and accurate apposition with the same layer of tissue in the portion of plant which is to be grafted, so that these two different tissues will ultimately so grow together as to form one single stem or branch. In order to do this the stock upon which the graft is to be placed is cut off entirely in a transverse direction, leaving a circular flat surface. An incision is made into the margin of this transverse section, and if necessary a portion of the tissue of the stock may be actually excised. The graft, or the scion, which it is proposed to implant on the stock is then inserted into the aperture so made, the greatest possible care being taken to make sure that the different layers in the one correspond exactly in position to those of the other. That is what is meant by saying that the two must be placed in accurate apposition. In this matter the plant surgeon acts in exactly the same way as does the human

surgeon, who in stitching up a cut he has made in the body of his patient takes the greatest care to see that similar tissues are joined together. He stitches skin to skin, mucous membrane to mucous membrane, and so forth, because he knows that only by so doing can he get a good, sound union without an unsightly scar. So that here, again, we see that the principles which underlie these interferences with plant and animal life--all these surgical operations—are essentially the same.

The scion, or graft, which has been carefully prepared and trimmed so as to fit exactly into the portion of the stock made ready for it, should bear at least two buds, which should both be perfectly healthy. When the insertion has been made—that is, when the scion has been dovetailed into the stock, much as the handle of a bat is dovetailed into the blade—the wounds caused by the operation are covered up—as the human surgeon dresses his wounds—by some material which will protect the cut surfaces and aid in the union between the two tissues. Such material usually consists of wax or putty, or of some compound, the influence of which is the same.

THE METHOD OF SHIELD-BUDDING

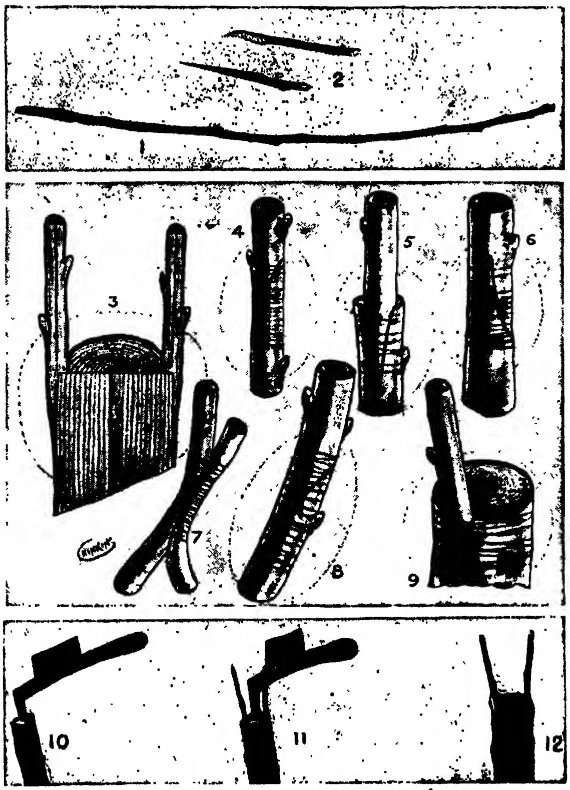
1, Line of cut; 2, bud cut out; 3, woody part removed; 4, incision in stock; 5, end partly inserted; 6, end fully inserted; 7, method of binding up.

Examples of the manner in which this operation is carried out will be seen depicted in the illustrations in this chapter, which show exactly how it should be done. If the operation has been successful, there will be formed an actual organic union by means of continuity of tissue between the graft and the stock. This union will allow of the passage of nutritive juices from the stock to the scion, by means of which the life of the latter will be maintained, and not only the life but the growth, as will be evidenced a little later on when the buds on the scion develop into actual branches. The stock extracts the nourishment from the soil, passes it by means of its own nutritive juices into the grafted scion, which in its turn in virtue of its own life is enabled to build up these juices into tissues of its own kind, and so ultimately gives rise to an entire tree-top with many branches of its own, living almost as a parasite lives upon its host, which is in this case the stock.

This process of the growth of the graft does not necessarily mean that the growth of the stock ceases. Indeed, it is quite a common thing to find that while the grafted scion is producing its own branches at the top, the original stock is also sending out branches down below. In this way the curious sight is sometimes seen of what appears to be one plant or tree bearing two entirely different fruits, or blossoms, or leaves, in different parts of it. So one may find, for example, medlars coming to maturity as a fruit in the upper branches, while quinces are forming down below. The medlars represent the fruit of the graft which was joined by the process of grafting on to the quince stock which has been allowed to produce branches also. We need hardly say that this is not the ideal result of the fruit-grower, who carefully removes signs of the lateral growth from time to time, in order that all nutrition may be sent to the graft itself, which is the portion of the tree that he specially values.

Before we leave these interesting processes of budding and grafting and so forth, one or two words must be said upon the much-disputed subject of graft-hybrids. A hybrid is a plant produced from two original parents which have different properties and characters, the most ordinary way of producing such a plant being by making a cross between the two by transferring the pollen of one to the stigma of another. The resulting plant, the hybrid, differs from both the original parents, being either midway between them in character or approximating to one or the other.

It will be observed that this process of hybridising depends upon the union of germ-cells. Now, it has been repeatedly asserted, particularly by practical gardeners, that a hybrid plant can also be produced by budding or grafting, and such a plant is termed a graft-hybrid. One such plant of the laburnum group (Cytisus Adami) has occasioned considerable discussion in botanical circles. It shows a curious mixture of the features of an ordinary yellow laburnum and the purple laburnum. Most of the flowers appear to be equally like both parents, with some minor differences. The corollas are of a dirty red colour, suggesting the mixture of the purple and the yellow. But the strange thing is that on some of the branches there are a few blossoms having yellow corollas, others having half yellow and half purple, or other combinations and proportions. This tree is said to have been produced in Paris in 1826 by a grower named Adam, who inserted a bud of a purple laburnum into a stock of the ordinary yellow type, the resulting ingrowth having characteristics derived from both.



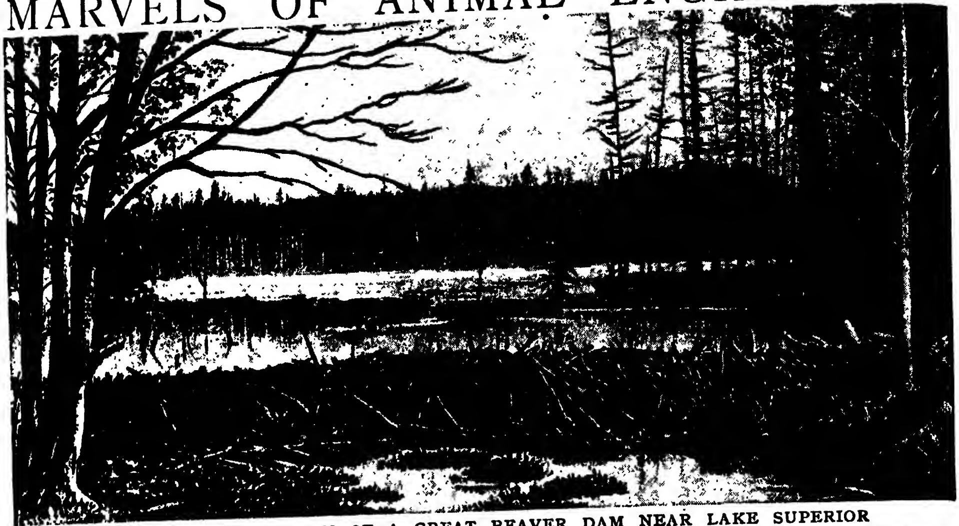
METHODS OF GRAFTING

1, A good piece of scion wood; 2, two scions ready for use for top grafting; 3, section showing crown or rind grafting; 4, splice grafting; 5, cleft grafting; 6, saddle grafting; 7, marching; 8, whip grafting; 9, notch grafting; 10 and 11, stock split and held open for reception of scions; 12, scions in position, wax having been applied.

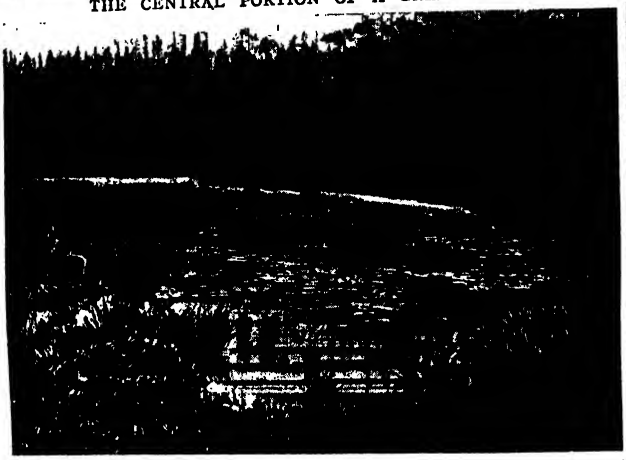
From this plant buds were sent all over Europe. The most interesting fact stated concerning it is that not only do the cuttings from the original graft-hybrid of Adam bear flowers of an intermediate character, which one might expect, but that some branches show other flowers which revert back to the type of the parents, while single flowers have half the characters of one parent and half of the other. Thus this graft-hybrid bears three distinct kinds of flowers, as combinations of the two parent forms.

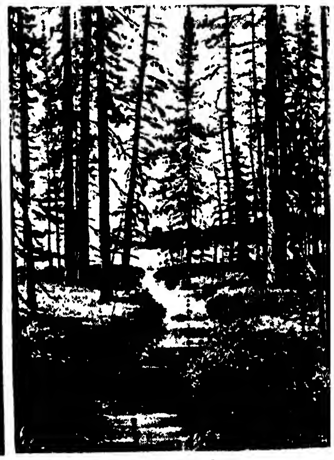
We have not space here to enter into all the details of the controversy which this curious state of things suggested, but it may be well to mention that the careful consideration of analagous cases in other plants, particularly in connection with the experiments made on the iris, have led many to the opinion that this so-called graft-hybrid of the laburnum was originally not a plant of that kind at all, but was a true cross between the yellow laburnum and the purple one. That is to say that the original plant of Adam was not obtained by process of grafting, but by a true hybridising or cross. Still, the point is by no means settled; and quite recent experiments in other directions show very curious mixings of parent characters, though not fusion of such. What is required, before definite judgment can be arrived at is the knowledge of whether or not the sum total of the characters of Adam's graft-hybrid are absolutely unique amongst hybrid plants whatever their origin may be.

Botanists do not all deny that such a thing as a graft-hybrid can be produced, because there is no reason to say that the protoplasm within the cells of the stock of the graft may not undergo a certain amount of fusion or mixture. If such a thing did happen one would then have a protoplasm in the cells of the graft having a character of neither of the two parents, but of an entirely new type—namely, its own. If such intermediate form of protoplasm were produced, then one would be prepared to find the curious mixture of characters which is asserted to have been produced in Adam's graft-hybrid.



THE CENTRAL PORTION OF A GREAT BEAVER DAM NEAR LAKE SUPERIOR





TWO CANALS DUG OUT BY BEAVERS TO CONNECT TWO SMALL LAKES

BEAVERS AT WORK CONSTRUCTING A DAM FROM LOGS AND FRAGMENTS OF WOOD

The photographs on these pages are by Messrs. Lewis Medland, W. P. Dando, and C. Reid

ANIMAL HOME-BUILDERS

The Intelligence that, through the Beavers, Finds Expression in Elaborate Engineering Works

THE MASTER CRAFTSMAN OF THE WILDS

MAN was not the first home-maker. He was not the first engineer. He was not the first to make provision against the morrow. He was anticipated in each sphere by the brute creation. Insects and birds, and certain of the mammals, set an example that he was slow to copy. Perhaps the imitation was unconscious; perhaps it was partly conscious. Certain native tribes, to some extent, regulate their diet by that of the monkeys; whatever a monkey eats, they note, a man may eat. We have learned from the animals how to hunt them, and civilisation has won medicine as well as food from the wilds by watching animals at their diet. It is not altogether inconceivable, therefore, that primitive man may have got some of his first ideas in engineering from the quadrupeds about him. Indisputably, when he shared their caves with animals, he must have envied the beaver its lodge and the burrowing creatures their well-organised subterranean cities. With his mind, with his hands, with opposable thumbs, with his erect carriage, he has outstripped all the rest of creation. The results that he has attained are, of course, incomparable, but the achievements of the beaver are almost as incomparably ahead of those of all other animals—" animals " in the common acceptation of the term.

The life of the beaver is really more highly organised than that of the mightiest gorilla or of the astutest monkey. The rough shelter of interlaced branches of the tree upon which it squats is the only attempt at a dwelling made by any of the exalted order of Primates. Yet the brain of the ape or monkey is the finest brain in the world next to that of man. It is surprising that with the imitative faculty so highly developed, the Primates have never essayed home-making. One of the two huge orang-utans at the London Zoological Gardens, Sandy, the beast which recently escaped and had wit enough to shake his keeper from the ladder upon which the man sought to capture him, has evolved a plan for getting water to drink. He thrusts a straw between the wires of his cage into a trough, soaks the ear of the straw in the water, then carries the latter to his mouth. Jacob, the orang next door, watched the manœuvre, copied, and improved upon it. He invariably uses four or five straws for the same purpose, so that he gets four or five times the quantity of water which his neighbour secures, and, incidentally, by his choice of that number, suggests some evidence of ability to count, untaught, up to four or five. Now, it is very strange that some equally imitative and adaptive Primate, in the course of time, never watched and imitated one of the building animals at work. With a monkey or an ape constructing a house rivalling that of the beaver, the simian family would have been on the way to progress on parallel lines to those pursued by man. One difficulty, of course, is that Primates and beavers occupy different regions.

But it is only the less exalted animals that build and store up food. Their habitations are regarded as evidence of degeneration in some animals—as evidence that, failing by other means to keep pace with the tide of evolutionary progress, they have had to crawl below ground. This argument does not apply to the animals with which this chapter deals, a group belonging to the rodent family, a numerous and specialised congeries of mammals, the majority of which will be separately considered. The list is headed by the beaver, our finest natural engineer. He was the first to throw a bridge across a stream, and he remains the only animal capable of the feat. He was the first mammal to build a home above ground, and to-day man is his only rival.

It is impossible to guess how the habit originated. The food of beavers consists in the main of the bark and twigs of trees, notably the willow; but in summer, when they leave the river and wander inland, they flourish upon corn and grain. It is suggested by a thoughtful naturalist that at some time early in their history a beaver may have gnawed through the trunk of a tree overhanging a rivulet, till it fell across the stream and formed a natural barrier, that held up the water to a permanent depth. To suppose that this hypothetical pioneer immediately grasped the significance of the accident, and finished the dam, and that his progeny at once learned the lesson and adopted the plan, is to credit the beaver brain with an intelligence and reasoning power altogether too high. But the process must have come about gradually by some such means. Had there been a beaver in the world that could suddenly dam rivers, build lodges, and make roadways and canals for the conveyance of his materials; and had such an animal transmitted his gifts to his offspring, he would have become the ancestor of a type of animal which, supposing its gifts to be progressive, would have challenged man for the supremacy of the world. For, eliminating all the fiction about the beaver's making windows to his lodges, and similar legends, his work remains the marvel of the animal world.

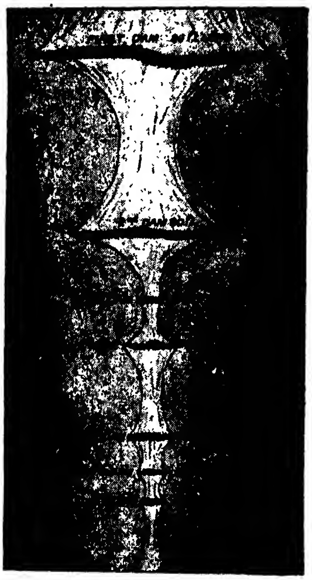


DIAGRAM OF A SERIES OF BEAVER DAMS BUILT IN A RIVER GORGE NEAR LAKE MICHIGAN

What does it mean? It means that he must estimate in advance the course of events in a stream, must realise that the abundant water of to-day may vanish, either from scarcity of rain, or through the supply being cut off by frost. He must reason out how best to combat this danger, and must find that the only way is to dam the stream, and so maintain a constant depth. Having got his waterway secured, he must provide a home that will be safe from attack by his enemy, the glutton, and at all times give him access to a sufficient depth of water free from frost, in order that he may reach his food stored beneath the stream.

And this is only half his work; his timber-felling far from the stream, his conveyance of the logs to the water, and the canals that he makes for the purpose, all require the planning of a marvellous mind. Strike out every suggestion of fancy and embroidery, and the feats of the beaver are still the most challenging fact in animal psychology. Says Auguste Forel: "It seems to require much less nervous substance for fixed or instinctive reasoning than for reasoning actual, individual, new, and combinative." And he describes instinct as reasoning organised, systematised, and automatised. Let us see for ourselves whether the beaver's work suggests "reasoning actual, new, individual, and combinative," or whether it implies only obedience to blind, beneficial impulse.

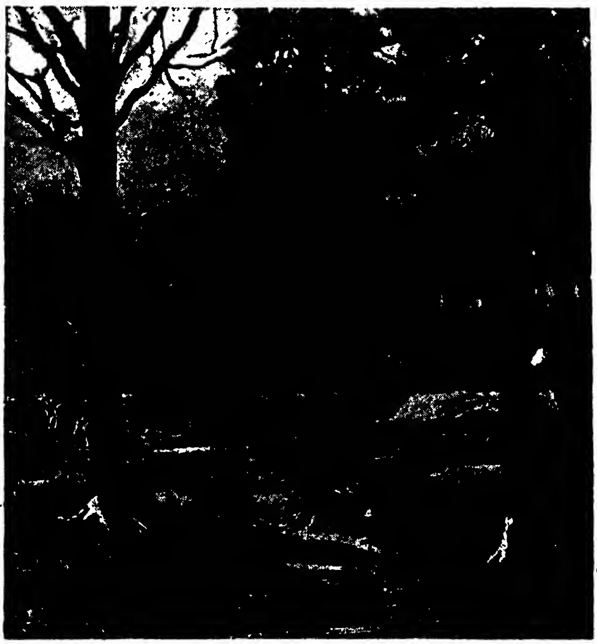
Beaver works are carried on for hundreds of years; Agassiz obtained evidence enabling him to state that one series of these works had been in continuous formation for a thousand years. The city of Montreal is founded upon prehistoric beaver meadows. We have now, however, to imagine a couple of beavers beginning work *de novo*. We have to remember that in Europe, where these animals have long been persecuted almost to the point of extermination, they may occasionally lapse into mere burrow-makers in the banks of streams. The beavers we have in mind, however, are those that remain among the vanishing glories of Canada. The earliest duty of our pioneers is to excavate a burrow in the bank, or throw together a roughly built, temporary lodge to serve as a home while defence and mansion are prepared.

The first problem to be determined arises from the stream. If it is a small and sluggish stream, a light dam of woodwork will suffice. If it is a swift-flowing rivulet, the case demands a more ambitious effort, and the dam must be made like a wall. The shape, too, has to be determined. A straight dam serves to check a gentle current of water, but to withstand a rapid flow a curved dam, with the convex face opposed to the current, must be built. Here, then, are problems calling for "reasoning actual, new, and individual."

A decision having been reached as to what form the dam shall take, the beavers set to work to cut down trees. Those nearest the water and inclining towards the stream are chosen, and gnawed through near the root. As a rule, but not always, the tree falls towards the water. The boughs are then bitten off and peeled. The bark and thin twigs serve for food; the thick boughs themselves are gnawed through into suitable lengths for the dam. The trunk of the tree is similarly served. The logs are removed from the land into the water by being rolled by the builders, who use their forepaws for the purpose, and push with their bodies, raising themselves upon their hind limbs, and employing the heavy tail as a lever. It is to be noticed that the thicker the branch or trunk, the shorter are the sections into which the timber is cut, obviously in reference to the strength of the beaver.

THE SUPREME NATURAL ENGINEER—THE BEAVER

The foundation of the dam may be either of mud and stones or of brushwood, or both. In either case the logs have to be securely anchored to guard against their being floated away by the stream. This is effected by their being thrust into the mud, or into brushwood already so attached. In the case of a lighter dam, building with logs and twigs now proceeds apace. Sticks and poles and twigs are interwoven and plastered with mud, so as to form a substantial but not invincible barrier. In the case of the solid-bank dam, as it is called, less wood is employed, mud and stones taking its place. The stones weigh from one to six pounds, and are carried against the beaver's chest secured by the forepaws. Mud is transported in the same way, and beaten hard with the paws. The heavy trowel-like tail is not used for the work. That remarkable tail is simply the rudder, though from the loud report with which it strikes the water as the animal plunges in it may be deliberately employed as an alarm signal.



THREE TREES IN COURSE OF DESTRUCTION BY BEAVERS, WHOSE DAM IS TO BE SEEN IN THE BACKGROUND

It probably took man a long time to make a sluice for his lock-gates. The beaver has his sluice, too. In the case of the woodwork dam interstices between the logs and twigs afford an outlet for surplus water by process of percolation, but it is different in the wall dam. Here the beaver deliberately leaves an opening at the summit, a well-defined channel through which the dammed-up water can rush when it reaches a dangerous height. Moreover, the size of this sluice is regulated by the beavers in accordance with the condition of their pond; being widened in presence of a freshet, and restricted when the water is low. Attention is given

constantly, so long as the beavers are in residence, to the stick dam, to guard against too rapid percolation and to the making good of waste at the base as the result of natural decay of materials. It is not uncommon to find one dam supplemented by a second, either close at hand or at some little distance down the same stream. This may be made in order that the one may serve as a sort of bulwark to the other, or it may be that the first has failed to dam up the water to a sufficient depth, owing to the configuration of the land, a defect which the second remedies. There are more plans in the work of a beaver than are dreamed of in the philosophy of most of us.

THE CHIPMUNK, OR GROUND SQUIRREL

The dam built, ample water is secured in which the beavers may safely swim without observation in summer and winter, more especially in the latter season, for they may roam away overland in summer and come back in autumn to repair their work and make ready for the snows. The lodge has next to be made. Here, again, discrimination must be exercised. If there be an island in the water, the probability is that the builders will choose that. They may build on the dam itself, or they may choose the bank of the stream for the site. Lodges vary considerably in size and design; they are not uniform and unvarying, like the cell of the bee, but are adapted to the natural conditions and to the changing levels of the water. Where considerable rises of water occur, the home is generally upon the bank. Some of the lodges are built wholly clear of the water, with burrows running down from the interior of the lodge to the bed of the stream; others are made with one outer wall actually in the water. The structure is of wood and twigs, the logs varying in size from a foot to a yard, and the whole is heavily plastered with mud, which, freezing in the winter, makes the lodge a stout fortress, which even the powerful claws of the dreaded glutton attack in vain.

The beaver long ago mastered the mystery of the arched roof. His home consists of two or more chambers, according to the age of the structure, and it is constantly undergoing repair and renewal. The chambers are oval, with stout arched roof, and extend to eight or more feet in diameter in the case of an old lodge, while the length of the whole lodge may be from ten or fewer feet up to as much as fifty feet. The interior is lined with mud and twigs and vegetable fibres, as are the tunnels which communicate with the water. These latter are masterpieces of animal ingenuity. One is known as the wood entrance, and is a straight bold tunnel running sheer down into the water. It is through this that the beaver passes, laden with good cheer, returning with viands from his larder, which he establishes at the foot of the dam. The food consists of bark and tender branches of trees, and as these occupy some space, he must have a straight run up into the house for them, hence the bold tunnel left for their admittance. The second, and it may be the third, tunnel twist and wind before entering the water, and constitute the highway to the pond for all but foraging expeditions. It is perhaps not too speculative to imagine that the wood tunnel may be guarded in some way when not in use, or the devious highways to the water would be useless; an enemy would enter by the woodway

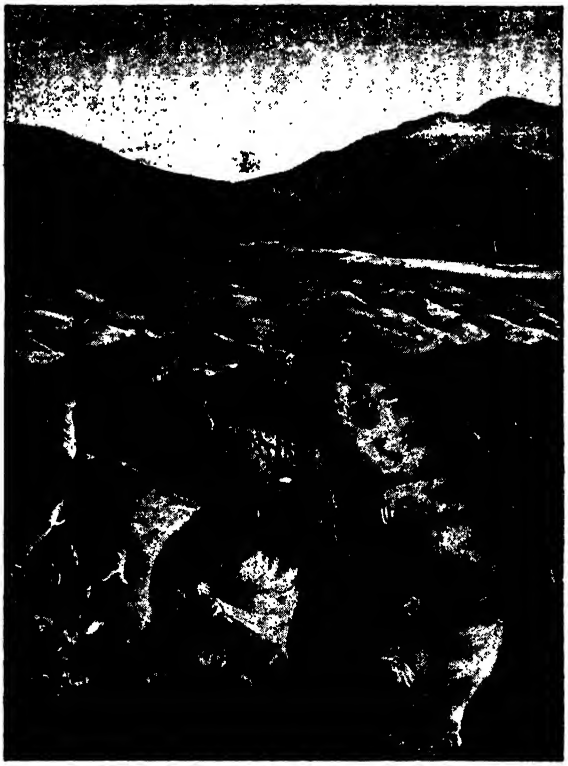
THE SUSLIK, CR GOPHER

without ado. All the tunnels are beautifully rounded, their roofs and sides and floors strengthened with twigs and fibres beaten into the soil.

So much for the dam and the lodge. The beaver is now free to enter the water at will. In winter he has a store of food hidden ready for his wants, and it matters not how severe the frost, there is clear water for him at the bottom to which his tunnels lead him. He runs from his lodge by way of one of these tunnels, enters the water—valves enable him to close ears and nostrils—he wanders under the water until he has got such food as he requires, returns by the wood tunnel, and shares his meal with his mate and offspring in as neat and effective a home as ever was built, save by the hands of man.

Time brings changes even for beavers, and the day arrives when there is no more timber to be felled within easy reach of the river. He has cut down all the adjacent trees, gnawed them into logs, and rolled them to the water. The time has now arrived when he can no longer bring down his timber in this way; the ground is broken and uneven, the task of transport beyond his strength. It is a new problem, and the solution seems really more wonderful than the work on dam or lodge. The beaver calmly sets to work and makes a canal. Surely this is beyond the province of mere instinct.

Simply with his paws the beaver excavates a channel, and clears it of obstructions in the way of roots and weeds. Then he cuts a connection with the river, and floods his waterway. That gives him a passage, it may be of some hundreds of feet. Into this he rolls the logs which he has cut, and sends them down to the river or pond with all the assurance of the accomplished lumberman. But the ground makes a sudden rise, and it is necessary to carry his canal higher. He cannot, because he is unable to defeat the laws of Nature and make water flow upward. This is another new situation, perhaps the most complex that he has yet had to face. He tackles it manfully. He builds a dam across the end of his canal, a catchwater dam, which collects all the water descending over a wider area from above, and he cuts a canal in which the water so caught can run. He has made a canal lock! His waterway has risen a foot, and he now has another stretch of highway along which to float his logs down to the canal dam, over which he pulls them into the long stretch of water flowing into the main stream.



AN ENEMY TO HUMANITY—THE BOBAC MARMOT, A DISSEMINATOR OF PNEUMONIC PLAGUE

This is no idle speculation, but sober fact. Mr. Lewis Morgan, in his monumental work on the beaver, has described one engineering masterpiece of the kind and illustrated it by diagram. Reduced to print, here is the outline of the canal. From the pond a water-level canal is cut for a distance of 450 feet inland. Then occurs a rise in the level of the ground to the extent of 1 foot. A dam, shaped like the arc of a circle, and 25 feet long, is constructed as a catchwater, which feeds a canal 25 feet long. Then comes another rise of 1 foot, and a catchwater canal dam, 100 feet long, but reaching out considerably farther to one side than the other, obviously with a view to trapping the water on the moister side. This gives another length of 47 feet, 1 foot higher than the preceding lock, and 2 feet higher than the opening stretch which flows at river-level. At the

end of this link the third rise of a foot occurs, and here the biggest dam of all is made—55 feet on the one side, 87 on the other, and with its concavity directed towards the high-lying land in order to collect all the drainage water and divert it into the canal.

There, then, is a perfect canal, with three rises and three locks and artificial collection of water. It carries cargoes of timber to the stream below, which in itself is no less a miracle of achievement for an animal than is the great Nile barrage for man. Man, with all his tools and appliances, excels the beaver's dams and canals more in degree than kind, and the beaver has only teeth and paws. Can it be wondered that the beaver is a sore puzzle to students of animal psychology, that they are driven to ask if something higher than instinct is not engaged in these marvels of engineering, of foresight, of planning, of battling with new and ever-changing conditions? Captive beavers do not encourage the belief in the possibility of higher mental faculties of the genus.

The beavers at the Zoo make their canals as to the manner born. They plaster their roof with mud, they complete with logs and twigs the house which a keeper has started for them. The plastering and canal-making suggest the following of instinct; the captives have not realised that they are in a new environment and need neither. But civilised man, placed in an entirely new environment, might unconsciously do some such grotesque thing in his day-dreams, as when any of us, in ordinary circumstances, sets out for one place and heedlessly walks to another to which he has been in the habit of going, but has not the remotest intention on this occasion of visiting.

We cannot carry the inquiry further. All we can do is to hope that Canada and Norway and the few remaining countries to which these extraordinary animals remain, will preserve them, and never mind the howls of soulless lumbermen who complain that the beavers tap their water or dam their logging streams. We had our own beavers in this country for ages, and the name lives in the designation of many a town and district. But they have been gone for hundreds of years, and we can look now for beavers only to Northern Europe and a vastly diminished area in the New World. Unique, and a complete puzzle in respect of its mental attributes, this king of the rodents ought to be treasured like the okapi and the last of the bison.

A GROUP OF HAMSTERS

After the beaver, the rest of the engineers among mammals appear inconsiderable, though, judged by the proper standard, they are wonderful little animals. Take, for example, the chipmunks, ground squirrels of Siberia, Eastern Europe, and North America. They are comfortable-living little creatures, of the sort that children like to read of by the fireside on a winter's evening. They make quite admirable underground dwellings, approached by devious galleries, supplemented by twisting tunnels to provide a ready escape in time of invasion by carnivorous foes. But it is the little animal's care for the winter season, when its home is frozen over, that charms the child. The chipmunk is as provident as a bee, as an investigation of one store revealed. In it, snugly hidden underground, were found two quarts of buckwheat, a quantity of grass seed, nearly a peck of acorns, some Indian corn, and a quart of nuts. All this store for three or four little animals scarcely bigger than an English squirrel!

The susliks, or gophers, again, are expert miners, constructing deep burrows communicating with airy, roomy chambers. Regular storehouses are established below to contain the winter's supplies. When autumn wanes the gophers retire to their fastness and make all secure and cosy by blocking up the only entrance. Thus they pass the winter, with ample food to sustain life throughout the dreary months. When

spring draws near they excavate an ascending tunnel running in the contrary direction to that by which they entered, and leave by the back door, as it were, the front portal remaining sealed.

They have a system of sentries and look-outs, but not in such perfection as the prairie marmots, erroneously called prairie dogs, in reference to the puppy-like yapping with which the sentinels, posted upon a hillock to survey the surrounding country, give warning of an enemy's approach. Theirs is an admirably organised community, dwelling together in great numbers in underground homes that are called "dog towns," or villages. But with all their care they cannot keep out intruders. They habitually entertain the rattlesnake, and, frequently, the burrowing owl. The reptile is an invader, not a guest, and dines upon the family of his hosts. It is surprising that animals which combine so well to build and guard their homes should not have wit enough for combination against this scaly foe.

These marmots, unlike the gophers, are purely herbivorous; the gophers supplement a diet mainly vegetarian with mice and young birds, and are known to have feasted upon the bodies of slaughtered bison with which the prairies were once dotted. With its more varied diet, the gopher should in time outdistance the marmot. All the marmots resemble each other pretty much in habit and in the wonderful homes that they construct below ground. Many lay up a store of provisions against the winter, but this is not the case with the Old World marmots, which sleep so soundly through the time of frost and snow that they need no food.

There is one marmot under a deadly cloud of suspicion to-day, and that is the bobac marmot, which ranges from the western frontier of Germany, eastward through Galicia and Poland, across Southern Russia into Asia. The bobac exists in immense numbers in the country crossed by the Manchurian Railway, and in the summer thousands of Chinese flock out to hunt it for the sake of its skin, which comes to Europe to be sold as imitation sable and marten. For the last sixty years it has been known that plague affecting the respiratory tract rages among these animals every September and October. The stricken die in their burrows and there infect the next generation frequenting the same subterranean citadels. These animals, hunted, killed, skinned, and the flesh eaten—fever-stricken and healthy alike—have infected the hunters, who carried the plague back with them to China, with the frightful results seen in the winter of 1911. How the infection is communicated to man is not yet definitely known, but the story that the bobac is free from fleas, the great carrier of the disease, has been exploded by Dr. Petrie, of the Lister Institute, who has found thirty-six of these parasites on the bodies of twelve marmots.

A FREAKISH COLLECTOR—THE VISCACHA

Two remarkable miners are the hamster and the viscacha. The hamster has the more ambitious dwelling, with many corridors, a complete suite of rooms for the family, several granaries, one for each kind of corn, and one for fruits and roots. Quite a model home is that of the hamster, and so well do the animals thrive that at times they become a serious menace to harvests in Europe and Asia.

The viscacha is master of a remarkable home, too, an underground labyrinth of tunnels and chambers. But whereas the hamster is as clean and fastidious as a badger, the viscacha has the instinct of a rag-and-bone gatherer. He stores at the huge entrance to his colony all the refuse of his food, and roams far to collect things to add to his collection. When a friend of Darwin lost a watch on the Argentine pampas, he looked no farther than the home of the viscachas, and there he found it, displayed to advantage amid bones, stones, and thistle-stalks. Having become home-owners, the viscachas gratify a passion for property by their rubbish heaps, and in this resemble the bower-birds.

A BRAIN CELL THAT IS A LINK OF THOUGHT

A MAGNIFIED PHOTOGRAPH OF AN "ASSOCIATION" CELL, STAINED TO SHOW THE REACHING OUT OF THE FIBRES

This striking photograph was taken for POPULAR SCIENCE by Dr. F. W. Mott, F.R.S.

MAN'S ESSENTIAL LIFE

The Dependent Yet Dominant Nervous System, for the Sake of Which the Other Systems Exist

THE SUPREME FUNCTION OF MIND

"WHAT'S past is prologue," as Shakespeare says. We have described bones and muscles and glands, the heart and the blood, the lungs and the digestion, but none of these is an end in itself, nor all of them put together. In detail, they differ in man and the lower animals, but in no essentials. They clearly do not live for themselves, but for each other and for the nervous system, in which alone we find the characteristic organ of man. They support the nervous system, and it rules them; but though the first statement needs no qualification, the second does. Beyond doubt, the systems we have described support or serve the nervous system. Its powers of self-support are practically *nil.* It is shut away from the external world, and entirely depends for nourishment, ventilation, and cleansing upon what the blood brings to it and takes away from it. While other organs and tissues spend much labour in producing compounds that feed, or stimulate, or soothe the nervous system, it performs no glandular functions itself, we believe; and though it certainly produces many and various chemicals, these are highly objectionable to itself, requiring the most rapid and complete removal, and are of no use to the rest of the body, which, indeed, has to burn them up or throw them out.

This dependence of the nervous system has reached an extreme point. Other parts of the body have some power of what is called regeneration. Skin-cells and gland-cells, and many others, can divide and multiply, increasing their numbers or compensating for loss. But no nerve-cell can divide. The poisoned nerve-cell can recover; and we are learning that even nerve-cells that have been chronically poisoned with alcohol for years, and were thought to be dead, may recover if the poison is discontinued. But if a nerve-cell dies, none other can divide so as to replace it. The infant at birth possesses all the nerve-cells it will ever possess. True, as we shall learn, not all may develop, but there will be no cell-division in any nerve-cell in any circumstances. The nerve-cell is so highly specialised that it has lost this characteristic and necessary power of all typical cells. The consequence is that the nervous system is gravely limited in its power of compensating for damage, and therefore requires more care and protection than ever from those systems of the body which we have already described.

In return for their service it rules them, but the rule is much less absolute than we have until lately supposed. Thus the white cells of the blood are not under the control of the nervous system at all, nor are the ciliated cells that line the respiratory tract and are found in many other parts of the body. Again, though digestion is largely under the control of the nervous system, we find that the secretion of the digestive glands is by no means wholly under nervous control. The body is united in a double fashion—first, by the nervous system; and, second, chemically. The chemistry of digestion is largely a series of reactions, of which each stage chemically conditions the next. Thus the bowel produces a substance called "secretin," which is absorbed and stimulates the pancreas to work. This is chemical stimulation, chemical co-ordination of the body, quite distinct from nervous stimulation and co-ordination. We owe our gaining of this great new conception chiefly to the work of Professors Starling and Bayliss, of University College, London. We are learning that, both in health and in disease, the body is constantly producing and distributing substances now called "hormones," from the Greek verb hormao—I stir up, excite, summon, rouse to action.

That is what these hormones do; and by them the various parts of the body are constantly sending messages and giving orders to each other, and thus achieving a unity and a common action, which is just what the nervous system also does in its way, and is no less indispensable.

From the point of the view of the philosophy, the true science, of the human organism all this is very important, for it helps us to understand the real physiological relation between the nervous system and the rest of the body. The nervous system does undoubtedly rule, control, direct, co-ordinate, the rest of the body; and unless it does so things go utterly wrong.

The Nervous System the System for Which the Whole Body Exists

But this does not mean that the nervous system exists for that purpose, as has been supposed. On the contrary, the nervous system only does what is necessary *in its own interests*; and a vast deal of bodily management and regulation, we now learn, is done independently of the nervous system altogether, but for the nervous system.

It is not the servant, not even the authoritative government, appointed by the people to serve them; it is the absolute object, end, and aim of the whole body, which exists for it and for it alone. In the rest of the body, birth and death are continually occurring—skin-cells, blood-cells, and so forth are born and die in millions daily. They and their fate are nothing. They are like the helots of ancient Athens, numerous, necessary, but allowed to exist only for the sake of the privileged few, in whom life reached its highest forms. Just so with nerve-cells. They are not born in the course of the history of the individual; or rather, they are born, once for all, long before his birth, and they last unchanged throughout his life, while birth and death go on incessantly beneath them, and in their service.

The Brain the Relatively Modern Structure Through Which the Soul of Man Reveals Itself

Ultimately, and in its essential nature, we begin to see, life is psychical. In another section of this work, where it was sought to reduce all existence to the fewest possible categories, life found no place. Ether and energy were regarded as ultimates, and a similar place was claimed for mind. Where, we may ask, does life come in? There is such a thing, and it is not named there. This is certainly the place to ask the question, for it matters supremely when it is asked of the life of man. The answer is that life is ultimately not ether, not energy, though it is lived in ether, employs energy, and transgresses none of their laws. Ultimately it is psychical. Even in the lowest possible organisms recent work has demonstrated traces of choice and educability—traces of what can only be called mind; and in man supremely does life reveal its essential nature.

The overwhelming significance of this, for religion and for man's outlook upon the Universe, must be evident, and we shall often return to it. If life be essentially psychical, if evidence of mind, however humble, be found wherever we look properly for it in the world of life, then the nervous system, and pre-eminently the brain, of man are simply those relatively modern structures in and through which the life of man, life as manifested in man, specially concentrates and reveals itself. The opposition between this view and that which regards man's mind as a consequence of his brain—a structure evolved by the ordered accidents of "natural selection"—is infinite, everlasting, all-important. Compared with this, nothing else matters; and the twentieth century may yet be recorded as that in which the mind of man walked out of the darkness of nineteenth century materialism into the wide light of knowledge, which asserts more surely and safely and durably what the glaring superstitions of the past served rather to distort than to reveal.

The "Psyche" Diffused Through All the Lower Organisms is Concentrated in Man

The first and the last function of life is mind; that was "in the beginning," and that comes first. The evolution of the nervous system in the animal world, culminating in that of man, simply means the superior concentration, effectiveness, and intensity, even to self-awareness, of the dim psychical activity which is doubtless diffused through the general substance of lower organisms, and which unquestionably remains diffused through the various cells of our own bodies, as we soon learn when we study the behaviour of white blood-cells, bone-making cells, ciliated cells, and many more. As Bergson says: "The lower we descend in the animal series, the more the nervous centres are simplified, and the more, too, they separate from each other, till finally the nervous elements disappear, merged in the mass of a less differentiated organism. But it is the same with all the other apparatus, with all the other anatomical elements; and it would be as absurd to refuse consciousness to an animal because it

has no brain as to declare it incapable of nourishing itself because it has no stomach."

We affirm, then, that the nervous system contains and displays the essential life of man, or of any animal that possesses a nervous system, in the highest possible degree. But we do not assert that the essentially psychical character of life has been wholly withdrawn from the rest of the body. Very far from that, indeed, is the trend of modern psychology. On the contrary, when we study the nervous system on the assumption that the mind is a product of the brain, we soon learn that there are facts of mind which the brain does not seem to account for.

Mind Finds Expression Chiefly Through the Brain, but Also Through the Whole Body

We look round, and find that the spinal cord plays a part in mind. Later, we discover what will soon be studied under the name of the "sympathetic nervous system," and agree that this, too, plays a part in mind. That is not all. We discover that there are facts of mind, not clear and defined, like a logician's syllogism, but nevertheless part of the mind, which can only be referred to the organs of the body.

In ancient days, men thought of the liver as the seat of passion, the bowels as the seat of compassion, and so forth. We do not think so now, but we do recognise that these and the other organs of the body play a real part in our psychical life. Mind is most displayed through the brain and the nervous system, but not through them only. In the concluding chapter of his "Autobiography," Herbert Spencer devoted much space to argument for the proposition that "the mind is as deep as the viscera"—that is, the internal organs of the body. No modern psychologist denies it. Mind is at the bottom of all our life. It was not invented by the brain, but it has evolved the brain as its most efficient instrument.

The Various Forms of Power Over the Body Exercised by the Nervous System

Thus, modern science is steadily returning to the view of Plato, that the body and its organs are the musical instrument, the "organ," of the soul, which plays upon them, and reveals itself through them according to the degree of their perfection.

All this is anticipation, but it is in its place nevertheless. Only one other general consideration is necessary, and then we can proceed to the anatomical and microscopic study of the nervous system. It is that the nervous system makes itself necessary to the rest of the body in a very remarkable way, not very long discovered, and not yet understood. Without any special study, we all know that there are nerves which order muscles, and nerves which record sensations; and we should say that these two express the whole relation of the nervous system to the rest of the body. But we find that, when the nerves running to any part of the body are divided, strange things happen. Of course, a muscle which has lost its nerve-supply is paralysed; but let us take some other structure—say, the transparent front-window, or cornea, of the eye. This is not a muscle, and has no motor-nerves running to it. Sensory nerves run from it, and tell us when it is touched or scratched. But we find that, inside the bundle of fibres that we call a nerve, running from the cornea, there must be some which do not convey any information from the cornea, but do carry something to it, For, in short, if the nerves of the cornea be divided, no matter how carefully it be protected, so that nothing can touch it, soon it will undergo serious changes and will ultimately die. What has happened to it ?

Why it Pays All Parts of the Body to Feed the Nervous System

The answer is that the nervous system exercises, upon every part of the body, an influence regulating nutrition, which is called its *trophic* influence (compare "atrophy," and "hypertrophy"). Trophic nerves run to every organ and tissue, and keep them well. What really happens we cannot tell at all. It might be merely that the blood-supply to the part is regulated by the nerves, which we know to be the case. But we may choose a tissue like the cornea, which has no blood-vessels in it, or we may check our observation in other ways, and we can prove that the trophic influence of the nervous system is something special, which does not depend upon, say, the exercise a muscle gets, nor upon the due regulation of the supply of blood to any tissue. It is something apart, but its importance is beyond question, for there can be no health in any part of the body which is not receiving a proper supply of this trophic influence from the nervous system. It follows that, if the nervous system be not properly looked after by the other tissues and organs, they very soon suffer in health. It pays them, so to say, to look after their master properly.

What, then, is this nervous system, in which the life and mind of the body are so amazingly expressed, and raised to their

highest in the self-consciousness of man? It is, of course, a collection of cells. They are not wholly collected in one place, but the quotation from Bergson has already told us that the closer grouping of the characteristic cells of this system, which we call nerve-cells, is a feature of the higher forms of animal life. The earliest nerve-cells are widely distributed throughout the animal body. To deny consciousness to such an animal is simply silly; it palpably wakes and sleeps, as we do; and if it is not conscious when it is awake, what is it when it is asleep?

The Widespread Nerves Become Linked Up and Grouped

But in time the nerve-cells find that they can be vastly more effective when they are grouped together, just as a collection of strings and keys, forming a piano, is more effective than a scarcely connected number of such strings all over the house. Thus we get what are called nervous ganglia. A ganglion is simply a collection of nerve-cells. Where we find, say, four or five ganglia grouped together, probably at the front end of an animal, nearest its eyes and nose and mouth, we cannot deny to this collection the title of a brain.

This collecting and linking up of nerve-ganglia has proceeded much further in man than in any other creature, and has reached such an extent that we find very nearly all the nerve-cells in his body concentrated in a continuous structure or organ which we call the central nervous system. Thus, if one were to deprive a man of all four limbs, by amputation at the hip-joints and shoulder-joints, he would not be the poorer by even one nerve-cell.

There are no nerve-cells in the limbs, none in the skin, none inside any of the muscles of the body, with the great exception of the heart. Yet the entire nervous system has developed from the skin layer of the embryo—that is, the layer next the outer world, which it is the business of the nervous system to deal with.

The Withdrawal of the Chief Nerve-Cells Into a Strong Bone Box

But, though it is now in better and really closer touch with the outside world, and has more power over it, it has withdrawn itself to an extraordinary degree, being not merely within the body and away from the skin, but being actually encased in a great box of bone, through a few holes in which it transacts all its business. Thus only the brain sees, but the brain lives in absolute darkness, and no ray of light has ever entered it.

The central nervous system can be, and will be, defined, and its outgrowths can be traced to the uttermost parts of the body. But we also find in the body what we can scarcely refrain from calling another nervous system, and this is known by the name given to it by the older anatomists, of the "sympathetic nervous system." The nerve-cells of this system are much more scattered. They are not found at all inside the skull and backbone. But they form ganglia in various parts of the trunk of the body, and the most intimate connections exist between the central nervous system and the sympathetic nervous system.

The largest ganglion belonging to the sympathetic nervous system is known as the "solar plexus," or "abdominal brain." This is by far the largest collection of nerve-cells in the body outside the skull and backbone. It lies behind the stomach, and is highly susceptible to blows. When we are hit in the "wind," or "winded," what has happened is that the solar plexus has been shocked by a blow; and we all can assent to the anatomical assertion that this plexus is linked up with other parts of the nervous system—not least with those which control our breathing or "wind."

The Obscure Puzzle of the Sympathetic Nervous System and Its Sense of Well-Being

But, really, the sympathetic nervous system is a great puzzle to anatomists, and we had better briefly discuss and dispose of it here. The prevailing notion among anatomists is that the sympathetic nervous system is the oldest part of the nervous system of man, the part which has, so to say, been left behind in the body-cavity when the rest of the nervous system has withdrawn itself into the skull and backbone. But there are many difficulties in the way of this view, and perhaps the only thing certain is that we cannot afford to despise the sympathetic nervous system. We know, beyond doubt, that it discharges most important functions, carrying many of the nerves that control the blood-vessels, for instance, and probably playing a large part in the trophic function of the nervous system. But especially are we to realise that the sympathetic nervous system plays a much more important part in our *minds*, in our feelings of happiness or depression, "fitness" or slackness, good or bad temper, than we suppose when we think of the mind as a secretion from the brain.

No one who has ever been "winded" should make such a mistake; if the solar plexus can give us such unpleasant feelings

when it [illegible] out of order, may it not play a large [illegible]t in other kinds of feelings when it is [illegible]rder? Those who know how i[illegible] or the life of man is his "organic [illegible]ll-being" will begin to see the [illegible] further hint be needed, let us [illegible]at kind of sleep, what kinds of [illegible] and theories of life, what kind of [illegible] fears we enjoy, when a heavy [illegible]ains undigested, and is vainly churned [illegible] the stomach, while we lie upon our back [illegible] so that the disturbance plays [illegible] upon the consciousness, dim but [illegible]dwells in our solar plexus or "[illegible] brain."

[illegible] for the central nervous system. It [illegible]ially a collection of nerve-cells. W[illegible] there is found some connective ti[illegible]od-vessels and lymphatics, but [illegible] cells are the essence of the system. [illegible] nerve-cell, however, is in many ways [illegible]ingly unlike all the other cells [illegible]nd requires very special description. [illegible]s a variety of projections or pro[illegible]ning from it; and the modern [illegible] the central nervous system regards [illegible] combination of vast numbers of [illegible]—each unit, a nerve-cell, with its various [p]rojections or processes, being called [n]euron. This neuronic theory of the [nervou]s system has held itself against [illegible] and is now fairly established.

[illegible] Examination of the Cells Through Which [illegible] Shines the Light of the Mind

The ce[nt]re of each neuron is the nerve-cell itself, or the body of the cell, as we sometimes call it. The cell may take many forms, often being remarkably large and striking in shape, like the large pyramidal cells found at a certain level of a certain part of the human brain, and shown in Dr. Mott's wonderful photographs in Part 1 of this wo[rk.] A nerve-cell always has a large and [illegible] important nucleus, and this [illegible]ows different appearances at di[illegible]mes. But we never see its [illegible] breaking up into chromosomes, [illegible]ther sign of nuclear division. [illegible]s cannot divide, but has devoted [illegible]ibilities to its own individual [illegible]t. The nuclei of the cells in [illegible] parts of the human brain [illegible]st exalted forms of material [illegible] the world, for through them [illegible] eminently the light of mind. [illegible]f nerve-cells as electric lamps, [illegible] a system, already presents [illegible], and will be found invaluable in [illegible] us to understand many facts of [conscio]usness.

But, after all, an electric lamp is only a special place on the route of an electric wire, and similarly a nerve-cell has its connections. They grow not from the nucleus, but from the general protoplasm of the nerve-cell. The nucleus has no textural connection with the processes of the cell, but we know that if these processes be at any point separated from the body of the cell and the nucleus they forthwith die. Thus the nuclei of the nerve-cells have a trophic influence upon the processes of the cells, as they have through those processes, or nerves, upon all the tissues of the body.

The Changes Made in the Nerve-Cells by Muscular Exertion

When we stain the nerve-cell in a special way we find that it contains a number of stainable, spindle-shaped lumps of something, which are certainly no part of the living protoplasm of the cell, but yet are a normal part of the cell as we see it. It has further been found that if an animal be allowed to exercise itself, or if nerve-cells be otherwise made to work, the nerve-cells involved, which can readily be examined if the exercised animal be killed, and sections made of the appropriate part of the brain, are now almost wholly deprived of these so-called "Nisst spindles." We can only believe that they are a store of nourishment for the cell, which it uses when it is discharging energy; and their disappearance after work helps us to understand the profoundly important nervous element even in what looks like purely muscular fatigue. After a period of rest these spindles are re-formed in and by the cell; and we can scarcely help instituting the just comparison between what we see here and the case of the specks of pro-ferments found before, but not after, meals in the secreting cells of the digestive glands.

What May Be S[redacted]graph of

The real pro[redacted]nerve-cell, apart from that [redacted] been found to [redacted] Th[redacted] pla[redacted] con[redacted] sho[redacted] here[redacted] cell [redacted] or [redacted] consider th[redacted]m, and which [redacted]rough the body of the cell fr[redacted]o another, if the cell has mo[redacted]leed, these processes are ca[redacted]he nerve-cell; and the fib[redacted]ntain and

consist of are really the amazingly specialised protoplasm of the cell-body. In short, what we call a nerve, such as the ulnar nerve, or " funny bone," behind the elbow, is essentially a bundle of fibres which are really the extended protoplasm of a great number of nerve-cells. These fibres are found together in bundles, are covered with a kind of insulating sheaths and so forth, but essentially they are the projected portions of the protoplasm of nerve-cells, just like the projections thrown out by the amœba, or the cilia of ciliated cells. We now understand why the part of a divided nerve which is no longer continuous with the nerve-cells from which its fibres sprang must degenerate. Those fibres are really in just the same case as a piece of an amœba that has been cut away and is no longer sustained in health by the nucleus.

The Effects of Alcoholic and Other Poisoning on Nerve-Cells

The processes of nerve-cells are of two kinds, and different cells vary widely in the number that they possess. The most important are called axons; and every nerve-cell that has not utterly degenerated must possess an axon, for by the axon alone does it give or receive messages or orders. The majority of nerve-cells, perhaps, have only one axon. Some, called bi-polar cells, have two axons, one coming from either end of the cell. Some have more than two.

But these cells, however many axons they have, also show, as a rule, a very large number of other processes, called dendrons. These do not form nerves, and do not extend far from the cell they belong to. It is supposed that their function is nutritive. They are said to be withdrawn into the cell during rest or sleep, but we cannot be sure of this. In advanced alcoholic or other poisoning of the cell, and also in senility, the dendrons degenerate in varying degree, and may become broken up. This may be the consequence of th[illegible]neration of the cell, or the [illegible] dendrons are the "feeders" [illegible]n neighbouring [illegible] one another, and [illegible] take some part [illegible] cell to another.

[illegible]nveys Impulses, [illegible] Its Own

But the [illegible]rvous system are for future [illegible]ile, we must look at the prop[illegible]e-fibre, now that we know its[illegible]veys what we call a nerve-cur[illegible]s impulse. Any given fibre [illegible]ulses in only one direction. [illegible] " mixed nerve," such as we find in a limb, there are many fibres which proceed from motor nerve-cells, and many which proceed from, and convey impulses to, sensory nerve-cells. But each fibre obeys the law of its own nature, and the current in each fibre is undoubtedly insulated from all the others.

The details of structure of a nerve-fibre may be studied at length, and certain varieties of type may be identified. These differences are trifling; and the essential fact is that a nerve-fibre is a living thing, made of specialised living protoplasm, part of the body-protoplasm of the nerve-cell.

The function of the nerve depends upon its life. It may die, or be poisoned, and will convey nothing, however it be stimulated, and though its material continuity be unbroken. Nerves can be removed from a freshly killed animal, and kept alive in " normal saline," or other fluids, for a long time, and their behaviour can be tested directly, and by observing their influence upon the attached muscle, if it be a motor-nerve that we are studying. We thus learn that a nerve-fibre is alive, and behaves like living protoplasm. It is of simple type, however, and is almost inexhaustible by repeated stimulation—very unlike the cell from which it proceeds. When it is stimulated an electric current is always produced within it, and passes along it.

The Nerve-Current Not Electric, Though Electricity Stimulates Nerves

Naturally, we suspect that a nerve-current must be an electric current. This is not so. The nerve-current moves along the nerve not at the stupendous speed of electricity, but at something like the rate of an express train. It is a change in the living protoplasm of the nerve-fibre, and it is instantly reversible when the stimulus ceases, so that the process can be at once and indefinitely repeated. There is no end to the possibilities of inquiry here, for all manner of drugs may be tried upon all manner of nerves in different animals; and we find that some substances excite motor-nerves, some excite sensory nerves—as sugar demonstrates in exposed teeth—and electricity is a stimulus to all kinds of nerves. Cold lowers the excitability of nerves in warm-blooded animals, and heat raises it.

When we trace nerves to their ends we find a variety of structures. The end of a motor-nerve is called an " end-plate," a kind of spreading out of the tiny fibres of the nerve so as to cover the greatest possible surface. The end of a sensory nerve may be a great variety of structures, according as

A BRAIN-CELL OF PURPOSEFUL ACTION, TERMED A PSYCHO-MOTOR CELL

cell of the brain, magnified some 2000 times, is shown here stained. In the centre is seen the clear, unstained nucleus, oval in ., and containing in its centre a round, deeply stained body termed the nucleolus. The body of the cell itself is seen to possess a ›er of processes, and a number of dark, stained clumps forming a mosaic. These latter are called Nissl bodies, and disappear in an exhausted condition of the nerve-cells, which leads some authorities to regard them as a source of nerve-energy.

ther we are studying touch or vision or ll, or what not. But a very large nber of nerves, arising from cells within central nervous system, never leave it. axon of any nerve-cell of this kind els a long way, perhaps from one side he brain to the other, or from the brain the spinal cord, or in many other direc- is instead of ending in a muscle e some sensory organ, it breaks and spreads itself out, and practically ... *body of some other nerve-cell.* observe then, that this vast collection nerve-cells which we call the central ... em is indeed a system, and not ... aggregation. Nerve-cells not ... ol other kinds of cells, but they ... r nerve-cells. And when we ... entral nervous system from this ... w we reach a great new concep- n, the world owes to the famous ... sician Dr. Hughlings Jackson, who died in 1911, and after whom is named what doctors call "Jacksonian epilepsy."

Dr. Jackson saw that the central nervous system is made up of various levels, essentially three in number, of which the lowest is the oldest in the history both of the race and of the individual, the middle level coming next, and the highest level last; and the middle level can largely control the lowest, while the highest can largely control the other two. Each level has its own characteristics, the lowest being concerned with the merely animal life of the body, the next with the simpler emotions and managements of the body, and the highest being the seat of the essential part of man. This great doctrine is now accepted everywhere; and with the statement of it our survey of the nervous system as a whole is complete. Our next concern is to ascertain how this system, of which we now understand the general structure, behaves in practice.

AN ILLUMINATING EXAMPLE OF DEFIANCE OF THE BODY BY AN UNCONQUERABLE MIND

ROBERT LOUIS STEVENSON, WITH MIND UNDIMMED BY PHYSICAL WEAKNESS, DICTATING HIS LAST BOOK TO HIS STEPDAUGHTER, MRS. STRONG

3ALANCE OF MIND AND BODY

How the Body must be Treated so that the Mind may Retain its Health

A NEW ASCETICISM FOR THE FUTURE

UR course hitherto has been simple enough, for we knew what to aim at, l the rest was detail. But when we have cussed the bodily needs of such things air and water, and light and sleep and vering, we pass to a new department of r subject, where personal conduct is more vidently involved, and where it is necessary be perfectly certain that we know what aim at. As to water and light, for instance, ı sane men would agree; but as to what ıllows, sane men may differ.

We have undertaken to discuss the health, hich is literally the wholeness, of man; d hitherto we have practically ignored s mind, which is part of the wholeness of m. That has not mattered so far, but it tters now, when we are approaching stions of exercise and diet, and must ide whether to serve the body as it ines is necessarily to serve the mind; ether we are to use our minds to find at our bodies like best, or our bodies to rve our minds; whether physical exercise necessary to develop our muscles because ought to develop muscles; whether ysical exercise is good or bad for brain ercise, and so on. If the writer assumes at man is his body, and the reader that an is his mind, there is no chance of e reader finding what he wants in these ges, which will simply disgust him; or, our views are reversed, and if the der comes to learn how to be a heavy-ight pugilist, he will certainly find nself disappointed, and probably feel nself insulted.

The first principle of all the pages that are ollow must therefore be proclaimed; and ver we depart from it—which the writer hygiene is constantly tempted to do—we st repent and retract in advance. To s principle—directly based on the scienti-study of life and of man—we shall here give the name of the New Asceticism—a term that must now be defined. But we may note that the word "asceticism," which we commonly use to mean some form of self-denial, has no such necessary meaning, but literally means exercise. We shall do well to understand this fully before we come to tackle the problems of exercise, physical and mental. Meanwhile we see that the vastly ancient idea of asceticism, to which so many great men have subscribed, need not, should not, involve any denial of the body, any outrage upon it, any mutilation of it. The inherent idea of the word is that something, presumably the body, should be exercised, for the purpose of something else, presumably the mind. And this prepares us for the proposition that the difference between the old asceticism and what the writer calls the new asceticism depends upon opposite ideas of the relation between mind and body.

The cardinal principle of all asceticism is that the *psyche* is the all-important part of man, and that the body exists to serve it. This idea happens also to be scientifically true. It is a great conception, of which every age has need, our own not the least, and we here assent to it unreservedly. We shall condemn as erroneous, but not despise as unworthy, the practice of all who have tried to exalt the mind at the expense of the body; and we may now define the old asceticism as the belief that a whole truth, and not merely a half-truth, was expressed by the doctrine of the antagonism between the interests of mind and body. According to that doctrine, so far as the supreme interests of the soul were concerned, the body was only an enemy and a nuisance. Everything that it desired, or that encouraged it, was necessarily an affront to its irreconcileable enemy the soul. Only by consistently thwarting, starving, repressing the body

could a man do his duty to his higher part, and there was no discharge in that war.

No doubt the body is often a burden, and its needs a hardship, and we incline sometimes to rebel. The nervous system insists upon sleeping away something like one-third of our lives, in vegetable fashion. Many a man, not only the pleasure-lover, but especially the student of any order, resents that necessity, and tries to overcome it, in the interests of his mind and its activity. The results are often appalling, and yet we must honour the man who was at work "while others slept."

"And gentlemen in England, now a-bed,
Shall think themselves accurs'd, they were
not here;
And hold their manhoods cheap, while any
speaks
That fought with us upon St. Crispin's Day."

It will therefore be a problem for the new asceticism of the future to learn such control of the nervous system that all or many of us may be able to sleep so *deeply*—that is, so *quickly*—as to spare more time for the waking life. But this is not a task for ignorance to essay upon itself; and many are the disasters wrought by the old asceticism upon the mind, in the supposed interests of the mind, because it did not know that long vigils may damage the brain, which is the organ of the mind.

The Troublesomeness of the Attentions which the Body Demands

Then, again, we spend much time in dressing and undressing, and in washing. We cannot even have our useless nails attended to once and for all, but have to remember that they will not even keep clean for an hour at a time. We have short enough time in which to live, and yet we have to wait upon these useless reminiscences of the claws which were once invaluable instruments of life.

Similarly there is the problem of the hair; and while this is serious enough for everybody, especially if we try to keep the scalp clean, most men feel impelled or required to shave the hair of the face. Science offers them some warrant for the immense waste of time, certainly. It is not merely that the shaven chin is more likely to be clean and to bear no infection, but also that the hair of a man's face is undoubtedly a reversion to a more animal state. Here, as elsewhere in so many respects, the child prefigures for us the future of the race; and the man who keeps his face like a boy's is doubtless instinctively aware that he thus counterfeits the maintenance of the highe type from which he began to fall at pubert But still the waste of time is opposed to th idea of asceticism; and at present not eve the Röntgen rays promise to furnish a saf and final depilatory.

Add the need of eating and drinking brushing the teeth, and so forth, and we se that the burden of the body, though largel made pleasurable, is a very heavy one Perhaps we should realise the weight o this burden of ours if, instead of our ow bodies, it were someone else's upon whic we had to wait incessantly, feeding an scrubbing, and clipping and paring, an dressing and undressing it every day, an never a single holiday in our lives. On almost wishes, at times, when mental in terests are absorbing, that it were possib to be rid of one's body altogether—say by taking it out and dropping it in the gutte some dark night.

The Body as an Old Servant of the Family, Spoiled if Pampered

That, practically, is what the old asceti cism was always trying to do, just becaus its theory of the relation between min and body was unsound. But the body i a servant which, however troublesom and vexatious, and even humiliating, in it reminders of the brute, is yet indispens able to our welfare. This is an old servan of the family, and it pays us to treat hin well, though it is disastrous to make o him a pampered menial, for whom we soo come to live. His welfare is never an en in itself. That sounds reasonable enough but it has serious consequences. Thus, a we shall see, though the new asceticism must assert the value and the duty o exercise, it has only contempt for th ludicrous cult of muscle which is one of th follies of the age.

The Error of Caring for the Body for its Own Sake

We have to look upon the body as th temple of man; we must worship the go it enshrines, but to worship the templ itself is mere idolatry. Many sensible and many profound people are nowadays inclined to protest against the modern interest in health, on the ground that it concerns itself too much with things which are only means to ends, and not worth anything in themselves. The Psalmist was right to remind us that the Lord "taketh not pleasure in the legs of a man;" and though we shall discuss the physical exercises that concern the health of the legs of a man, it will not be that the man shall

boast of his legs, but that they shall carry him well where he wishes to go.

The old asceticism, with its theory of the relation between body and mind, was always bound to go in the direction, at any rate, of suicide; and it often went as far as physical mutilation. In general, the body was to receive the minimum that would keep it alive at all, and the soul would profit. But we cannot agree. We have the same end in view, but we repudiate the theory on which our predecessors sought to attain it. We do not believe that the *psyche* is at its best when the body is at its worst or lowest compatible with life. True, many people—by no means all—seem improved in mind by illness or weakness; many who are always fine become finer still. But, on the whole, we find that physical ill-health leads to mental and even to moral ill-health. Our lunatics are physically ill and weakly; and they improve, in the great majority of cases, when we can get more flesh and fat upon their bones, and improve their digestion. Certainly all people do not need the same advice in this matter; but no less certainly we now believe that the relation between health and holiness is not only etymological but also physiological, and we must act accordingly.

How Physical and Psychical Needs go Hand in Hand

This will not mean licence, for licence does not mean bodily health, and therefore does not serve mental health, any more than deprivation does. Indeed, such are the present habits of the majority of those who are not in monetary need (and of many of those who are) that the new asceticism will by no means always vary in its prescriptions from the old, and will be bound to lay chief stress upon our habits of physical excess, as in eating and drinking, rather than upon the tendency to undue denial of the appetites and needs of the body. Except, probably, in the matter of sleep, it is very far from being a defect in meeting the requirements of the body that prevents most of us from reaching our full height—and length here below—as *psychical* beings; or, in other words which really mean the same thing, though they sound so different, from enjoying life to the utmost possible for us.

In so far as the old asceticism was a protest against physical excess, we can have no quarrel with it to-day. The reader—present company, no doubt, excepted—may be warned as to what is in store for him when we come to study diet. There is really now no room for doubt, practical or scientific, that the great majority of well-to-do and many ill-to-do people are guilty of such excess in the matter of food and drink as it cannot long be well to do. It is not merely the body, observe, that we are now thinking of, but the mind, or the body in relation to the mind. The argument is not merely that most of us simply eat more than we need, or that we carry about with us more fat than is required for the warmth or protection or reserve needs of the body, but that we eat and drink more than is good for the health of the mind, and, above all, for the *longevity of the mind.*

The Relation between Excess of Diet and Premature Mental Decay

This is a great question, which will fall to be considered when we come to study the problems of old age. Meanwhile let us beware of supposing that growth, maturity, senility, and even something very like death are confined to the body alone. There is the mind to consider as well; and history is full of cases, as is the present, where people have prematurely lost their mental powers because, as we now begin to see, of dietetic excess of some kind, at least in the majority of cases. Indeed, no one yet knows what should be the application of the word "premature" in this connection. But we may make the anticipatory guess, derived from the records of great biography, that too old at forty need not—should not—apply to the mind, nor even, we may dare to believe, too old at eighty.

There is no inherent reason why the saying of Schiller should be true, that the lamp of genius burns quicker than the lamp of life. On the contrary, the mind, even here on our planet, may often all but visibly survive the body. Certainly there are octogenarians among us to-day whose names are known and honoured not wholly for what they have done, but for what they are doing.

The Need for the Preservation of the Youth of the Brain

Some of them, though very probably deaf, lame, muscularly feeble, though perhaps even "palsy shakes a few, sad, last grey hairs," are doing fine work to-day, displaying the great spectacle of essentially young heads on old shoulders, enthusiastic and experienced together, which a wise hygiene promises to many more in the future.

Some may say that the difference between these few and the many lies in the quality of the mind. But it is not in the least a materialistic assertion that the difference lies in the quality of the part of the body we

call the brain, which is the organ of the mind. The mind can only play on the organ it has got, so to say. If a man has good and fine mental qualities, and takes proper care of his mental organ, those qualities will not leave him. The brains of the old men whom we have described are still relatively young brains. It cannot be pretended that any brain at eighty is what it was at thirty or forty, but many an octogenarian brain is structurally and practically younger than many an ill-used brain of half its nominal age.

Care of His Nervous System the First Duty of Man

The brains of the wise, who practise the new asceticism here preached, have always been their owners' first care. They have not been systematically exposed to food-poisoning or drink-poisoning or drug-poisoning. Thus the legs of a man may grow lame, his skin wrinkled, the lens of his eye dim, the joints of the little bones of his ear stiff; but so long as his brain is supplied by soft arteries with pure blood, the man himself, as we wisely say, will be *all there.*

Hence we reach the simple, practical principle of the new asceticism, with which even the most thoroughgoing materialist can scarcely quarrel. It is that the essential part of the body of a man, which it is his business to take care of, is his nervous system. The anthropologists tell us that the brain is the characteristic organ of man; and Professor Forel, an almost supreme authority, has well written that: "With human beings the brain is the organ of the mind, and there is far more justification in what we know, nowadays, for saying 'The brain is the man' than Buffon had in his time for saying 'The style is the man.'" It would be more accurate, perhaps, to say the mind is the man, or the *psyche* is the man; but as we are here discussing not philosophy but practical hygiene, the brain is the man will serve as the key to our argument.

The Soul Manifests Itself Chiefly but not Exclusively in the Brain

The "average sensual man," then, is one who, forgetful of his high estate, uses his brain to serve his body, to find and purchase attractive food for palate and stomach, or to divert the centres in his spinal cord that exists for racial purposes, and not primarily for himself at all. Whereas the new ascetic is he who uses and manages his body to serve his brain, which is the substantial man.

An important note is here needed. The *psyche* lives not only in the brain, though chiefly there. "The mind is as deep as the viscera," to quote the final verdict of a great thinker. Therefore we shall not be able to despise the care even of the humblest organs if we find that their care is reflected in the state of the brain and the mind. In brief, the question which every wise man should put to himself, and which the writer on hygiene must attempt to answer, is: "How should I treat my body so as best and longest to preserve the health, the vigour, and therefore, so to say, the happiness of my brain, which, for practical purposes, is myself?" When the question is thus framed, the essentially ethical character of hygiene, as here understood, will be evident. The new asceticism has a genuine claim to be included in the religion of the future, and of the present, for now is always the appointed time.

We here repudiate the charges of materialism, Epicureanism, and preoccupation with less worthy to the exclusion of more worthy things, which some representatives of religion are bringing against the religion of health for the individual and the nation. We conceive the *whole duty of health* in such terms that it definitely serves morality, being health of the whole man; and we claim that, if we can establish the large dependence of the brain's health upon the body's, the care of the body becomes a religious duty, so long as it is directed towards the service not of itself, but of the mind. The duty of the clergy, surely, is not to decry the modern attention to the body, but to direct it to the worthy end.

The Powerfulness of the Reactions of the Body on the Mind

While Christian Science strives to erect into a whole truth the half-truth that the mind affects the body, we require to recall the other half of the truth, which is that the body affects the mind. The mere consciousness of bodily beauty or ugliness, tallness or shortness, symmetry or deformity, must affect the mind, and even conduct, as a whole. The reactions are various. The knowledge of beauty will make one woman vain, another sympathetic for the less beautiful; the knowledge of strength will make one man a bully, another very gentle. But the reactions exist; and if that be granted the body cannot be ignored. Again, it cannot be doubted that, other things being equal, the man with the most active digestion may tend to be the man with the most active mental energy; or, at any rate, the man with a high measure of physical energy which may be run into mental channels.

Again, the brain, like every tiny particle of nerve tissue, is intensely dependent upon the quality of the blood supplied to it, and thus "depending for its action on a due supply of blood, duly purified, must be affected in its efficiency by every variation in the development of this or that excreting organ." This means, in brief, that to attend to the health of the liver, the bowel, the kidneys, is undoubtedly to affect the blood-supply of the brain, and so determine its usefulness and longevity, as well as the kind of temper, in small things and great, that we may display from moment to moment. As Herbert Spencer has put it: "So, too, in active life the visceral derangements produced by overwork and anxiety are often followed by ill-temper. Even the recognised differences between irritability before dinner and equanimity (sometimes joined with generosity) after dinner suffice to show that when flagging pulsation and impoverished blood are exchanged for vigorous pulsation and enriched blood, there results the change in the balance of the emotions which constitutes a moral change."

The Brain an Original Endowment that may be Developed but not Added to

A creative hygiene, in any adequate sense of the words, is not possible for the adult. He is already long past the really constructive stage of brain-culture. So far as we can ascertain, intellectual work, diet of any kind, exercise, or anything else, will fail to add a single cell to those which his brain possesses, or seriously to modify the main lines, already laid down, of the connections between them. But if a creative hygiene is impossible, or nearly so, a recreative hygiene is not. What has been formed may at least be maintained, by means which we are about to define. And in recent years something has been learnt which the hygienist is entitled to remember. The number of cells in the brain cannot be increased. But we have found that there are a great many cells in the adult brain which, so far as we can judge, are doing nothing, because, though they are present and alive, they have never left their embryonic conditions.

The subject is still highly obscure. But these "neuroblastic cells," or "neuroblasts," as they are called, may very possibly be capable of response to suitable conditions, so that, instead of being inactive, they become active. This is not the same process as causing one's nerve-cells to divide and multiply, which is definitely known to be impossible. But, from the practical point of view, it comes to just the same thing. The future hygiene of adolescence and middle age may be largely concerned with the factors which persuade all one's nerve-cells to develop up to the point when they really begin to function; and it will very likely be found that the development of the brain may be continued far beyond the limits which any other part of the body can hope for. The discovery of these neuroblasts in the adult brain may give us the key to the fashion in which the mental powers of some persons appear to undergo a real increase far on into maturity or even senility of the body, and such exceptional cases may some day be made common.

A Fateful Warning—the Hopelessness of Renewing Deteriorated Brain Tissue

But that is speculation. What is quite certain is that the maintenance of what the brain already possesses is already largely within our control, and that it is only a quite small minority who, at present, can be acquitted of neglecting this duty, the discharge of which would have been worth so much to them. We cannot hope to repair damage already done to the brain, and the facts of damage should be remembered when we are proposing to avoid it. Here, again, prevention is better than cure, because it is largely possible where cure is not. If nerve-cells, in the brain or elsewhere, have already been destroyed, they cannot be restored. Their place will be taken by tissue which *cannot think*.

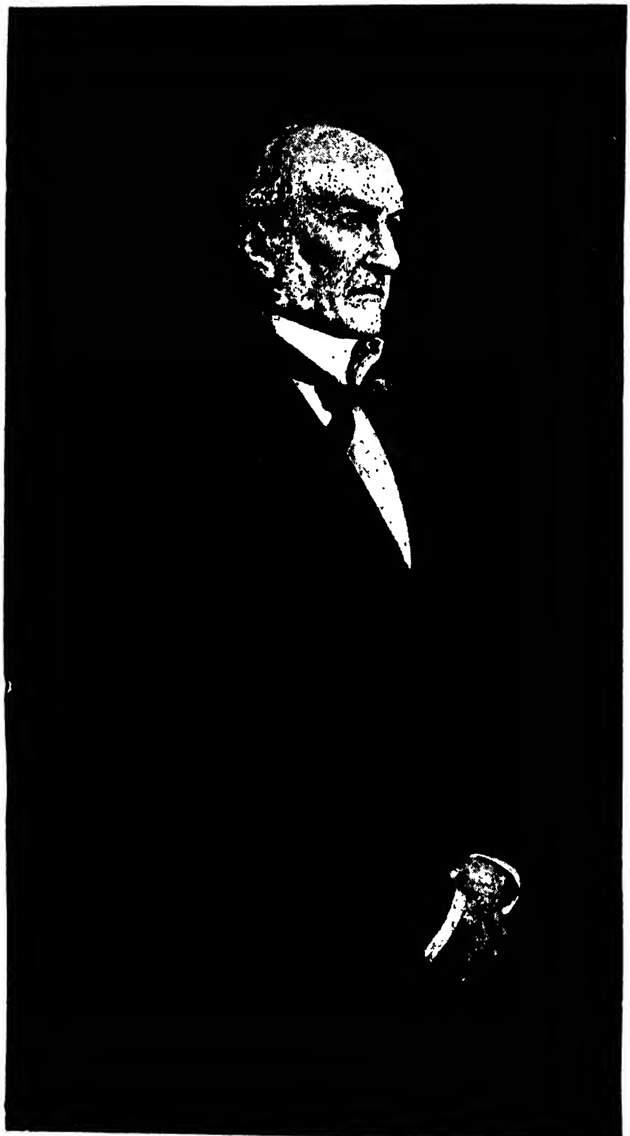
All cell-destruction is irreparable. Even a relatively humble structure like the skin is incapable of replacing a single hair-follicle, once lost. Much more is this true of the brain, whose cells are incapable of division. They are not so wholly without the power of recovery from chronic poisoning as used to be supposed, and the fact is hopeful for those who have to deal with the results of alcoholism.

How all Questions of Health Concentrate at Last on the Brain

But the verdict of science certainly is that, while creation of the brain is difficult or impossible, while replacement of its losses is impossible, its maintenance, which is the commonest of its needs, is far more possible than any but the hygienist recognises.

And, just because the body is really one, and just because the brain is in touch with every part of it, and is nourished by blood, the composition of which is affected by every part of the body, everything is liable to matter for the health of the brain. All

that we have already discussed bears upon the health of the brain, as well as of the skin; so also does our future study of habits, of the use of stimulants and narcotics, of exercise of the muscles, the senses, the intellect, the emotions, as well as the question of everyday diet. Though the next part of our discussion is devoted to physical exercise, which we commonly associate with youth, and which youth needs more than any other period of life, yet we shall see that it concerns other ages also, not least that time of life which the exponent of the new asceticism must particularly consider.



THE YOUNG MIND IN AN OLD MAN
This famous portrait of Mr. Gladstone, whose mind was young long after his body was old, is by Sir John Millais

We refer specially to the man of middle age, who suffers from no obvious, perhaps as yet no actual, disease, yet who is not quite so fit as he used to be, plays no more active games, is doubtful whether he has time nowadays for any exercise at all, is beginning to "put on flesh"—which is not flesh, but fat—has less initiative, less enthusiasm, and, in a word, is beginning to descend the hill of life. The pity is that so many of us start this descent as soon as we stop ascending. We develop our maturity, which is a long business and a costly, and then we begin at once to decline. We should not. At the top of the ascent of life we should come to a long, level tableland, whereon we should spend many years—decades, indeed—before we begin, ever so slowly, to slope away to the end. And it is pre-eminently the *psyche* that we are thinking of in this image.

Is it possible for those who have no sooner reached the height than they begin to descend so to manage their lives that they may profit by the climb for, shall we say, as long as the climb itself has taken, and longer? Undoubtedly it is; and the business of the new asceticism is to indicate how this may be done.

Certainly there is no occasion for the state of the man whom we have just described. He must expect to lose some bodily agility at forty or less. The experience of the finest cricketers, including those who have lived the wisest lives, is conclusive in showing that physical agility cannot be maintained unimpaired in the forties; but it is no less conclusive in showing how skill—which is a state of the brain, not of the muscles or joints—may be maintained almost indefinitely. The man of forty has no business

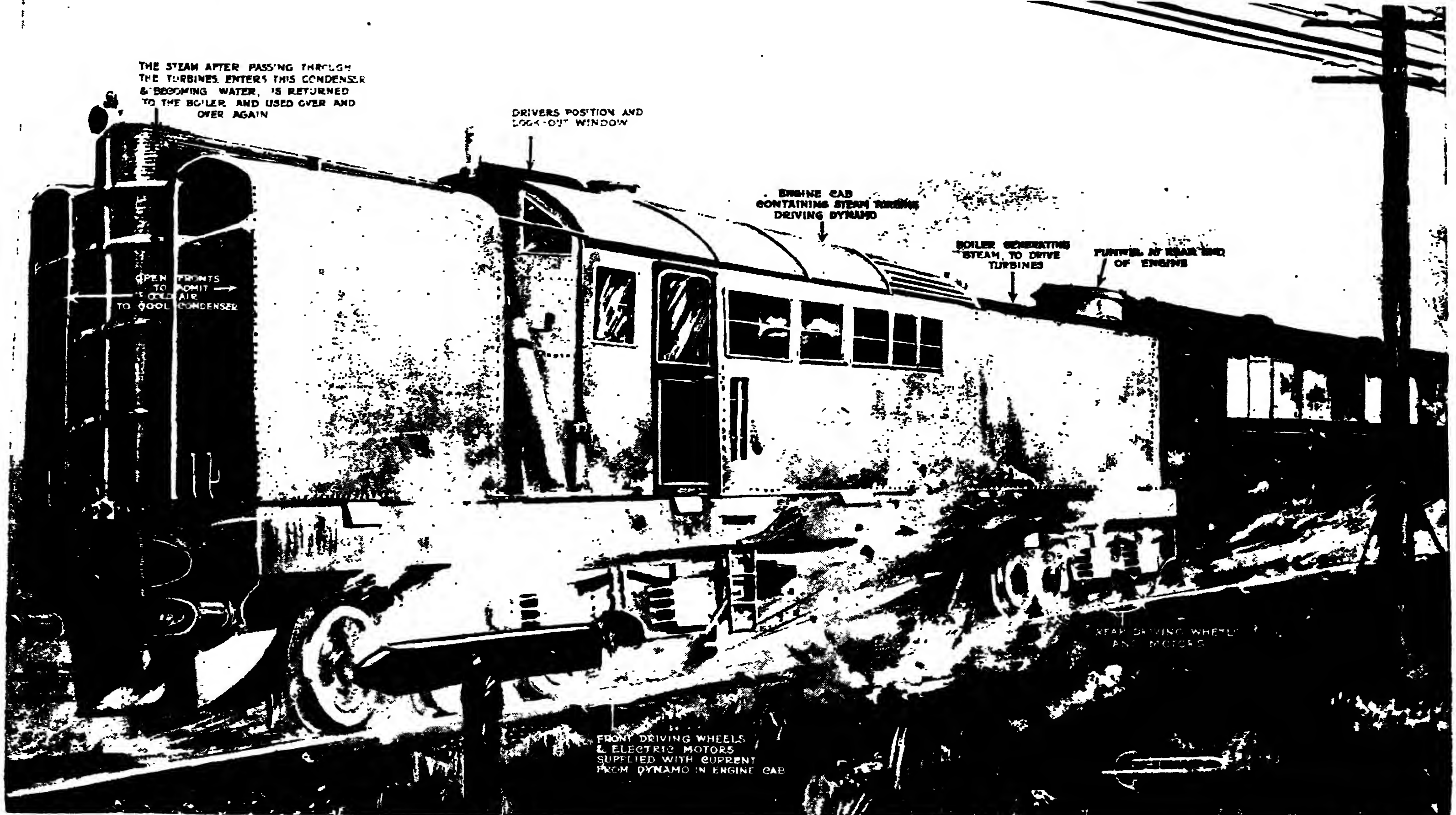
to lose his agility of mind for another three decades at least. He and we are the losers in that, just when his powers have reached their height and he has accumulated much experience, he begins to fall away. Many such men are responsible for this calamity themselves, or would be if they knew the facts which it is our business to unravel. They largely sin in ignorance, and are perhaps even doing their best, with pills and potions and belauded tonics, to repair their youthful vigour. Yet all the while they may be sinning against the laws of hygiene; and in a wiser age many such men will be looked upon as the obvious glutton and inebriate are already looked upon in our own day.

Knowledge is no less essential than good intentions. The man we have described has a multitude of counsellors in whom there is anything but safety. He may embark upon violent dietetic changes which rob him of essentials of diet or produce serious dyspepsia, perhaps with marked constipation, and thus aggravate his condition. He may damage himself with drugs, and even acquire a drug habit. He may undertake absurdly unsuitable exercises, perfectly adapted for the hippopotamus, but ill-suited for *homo*, and may thus strain his heart or his arteries in irremediable fashion. All these things are happening every day around us.

Attention to health must not be excessive, however well intentioned. It must suit the condition of the individual. It must not concentrate all his attention upon himself: such concentration may be the original cause of all the troubles which he seeks to relieve. The advice given must be absolutely disinterested, as very few advisers can afford to be. The fact is obvious when we read the advertisements of quack medicines. But it unfortunately applies, also, to much medical advice. The idle, overfed man who consults his doctor, and is told to "put on a sweater and run round the Park," does not profit, any more than the doctor does. The patient goes elsewhere to find, as he puts it, "a doctor who understands his case." The trouble was that the first doctor *did* understand his case. With these considerations in our minds we may proceed to the study of exercise, the right kinds and the wrong, those that develop muscle, those that serve the brain, those that shorten life, and those that prolong it.

THE STRONG MIND IN A FRAIL BODY
A quaint, decrepit little man was Immanuel Kant, the immortal philosopher.

A NEW FORM OF RAILWAY ENGINE SUGGESTED IN ORDER TO UTILISE A NEW MOTOR POWER



THE STEAM TURBINE ELECTRIC ENGINE RECENTLY TRIED ON THE NORTH BRITISH RAILWAY, AND LIKELY TO REVOLUTIONISE TRAVEL

The pictures illustrating these pages are by courtesy of Mr. Louis Brennan, Mr. Yorath Lewis, Mr. [illegible] the Great Western Railway, the London, Brighton, and South Coast Railway [illegible]

RAILWAYS OF THE FUTURE

The Systems that will Empty all Towns into the Country, and will Provide Moving Platforms

TRAVELLING AT 130 MILES AN HOUR

THE struggle between the motor-car and the railway has not yet become intense enough to attract public notice. The new and handy vehicle of the road is waiting for a cheaper engine and a more economical use of fuel. At present it is much too costly a means of travel for general utility, though farmers and market-gardeners are already combining to employ motor traction in sending their goods to large cities in cases where railway rates are high and railway methods slow.

When the cheap and improved motor-car arrives, driven perhaps by crude oil, it will undoubtedly revolutionise railway traffic throughout the civilised world. Moreover, a very economical motor engine would surely find its way into all coal barges and give a strong impetus to the revival and extension of our waterways. The result would be that a considerable part of the transport of minerals and heavy goods would be lost to the railways.

On the other hand, the railway itself is capable of being greatly improved. A smooth metal wheel running on a smooth metal rail is still the most ingenious and the most advantageous method of locomotion. The friction is lighter, the wear of the material is less, than in other means of travel. Engines, carriages, and tracks are not likely to disappear in the same way as the horse is vanishing before the motor-car. But it is likely that they will each be profoundly changed within the lifetime of many persons now living. Already the steam locomotive has been found to be unsatisfactory, and the Great Western Railway Company has been experimenting with a petrol electric engine. One car is now in regular service at Windsor. If it realises in actual practice all that is expected of it, steam-power on railways will be largely displaced by oil-power.

The Great Western car is fitted with a forty-horse-power petrol engine, which transmits its energy through an electric motor. So no overhead wires or live rails are needed. There is accommodation for forty-six passengers, and a maximum speed of nearly thirty-five miles an hour can be obtained. An absolute smoothness of running and a minimum of strain when starting and stopping are among the advantages of the new locomotive. But the most important point about it is that it is expected to prove more economical than the steam engine upon steep gradients, and more useful in light passenger services.

The question of economy is the grand question in the working of a railway. In its early days, the Great Western Company ran trains from Paddington to Slough at an average pace of sixty-nine and a half miles an hour. But from motives of economy only a little more than fifty-two miles an hour is now maintained in this service. The cause of this decrease of speed is not want of power in modern engines. For at times our trains attain a pace of eighty miles an hour; and experiments have shown that a speed of ninety miles an hour is not impossible. But, as things now stand, this high speed would be too wasteful of coal and too harmful to the rolling stock to yield a profit to the shareholders of the railway. Moreover, in many places it would endanger the lives of the passengers.

Two great changes are therefore necessary in our railways to enable them to compete with faster and more speedy forms of locomotion. The steam engine must be altered for the better, or supplanted by some other source of motive power; and the rails must be laid in a manner which will make special provision for extreme speed. Already, in other fields of industry, several cheaper sources of power than the steam engine

have been devised and put widely into use. The best results are obtained by turning coal and inferior fuel directly into gas, instead of indirectly transforming the energy into steam. The gas can be used immediately in an engine and made to move a mass of machinery, or it can be turned nto electrical power and transmitted to a distance. Then there is another cheap and convenient production of energy in the new engine invented by Dr. Diesel, in which oil is used, without any electric spark being necessary to ignite it. It is impossible to say which of all these sources of energy will eventually be found to be best adapted to the purpose of cheap and fast locomotion. The matter rests with the scattered army of able inventors, who are now competing against each other in the various fields of power. Those who are now [illegible] in the race to discover for mankind new sources of mechanical energy may, in a week or a month or a year, be suddenly and completely out-distanced by some competitor still struggling in poverty and obscurity. It is an exciting and inspiring spectacle, this contest between thousands of the most inventive minds of the modern world, all nobly ambitious to endow the human race with greater power. But the more closely one looks at it, the more difficult it becomes to assume the rôle of a prophet.

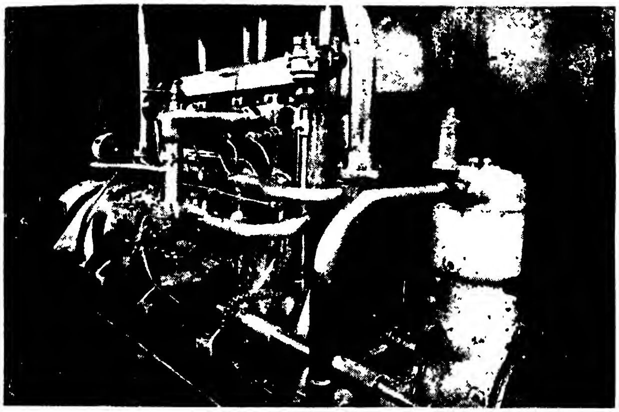
Our greatest chemist, Sir William Ramsay, is of opinion that on land, at least, electricity will prove to be the most economical and the handiest form of energy. The electrical engineer has harnessed the rivers, and in Schleswig-Holstein he is now building vast reservoirs to turn the pull of the moon on our seas into electric power; while in Egypt an attempt is being made with success to store and use the heat-forces of the sun. The only way to make the most of our coal-mines is to extract the gas at the pit-mouth, and transform its energy into electric power and distribute this by wire over all the country. Thus it looks as though the electrical engineer will win the race; and though, as we have said, one cannot be sure of this, it is significant that the two latest ideas of the railways of the future are based on the use of electrical power.

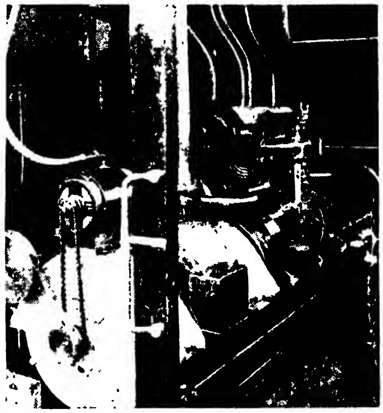
Safe, smooth travel at a speed of one hundred and thirty miles an hour is promised us by Mr. Louis Brennan, whose invention of the mono-rail is now being perfected on his experimental track in Kent. Mr. Brennan hopes to be able to give complete particulars of the latest improvements in the mono-rail

ECONOMY IN WORKING A RAILWAY—THE LIGHT, STEAM-DRIVEN "MOTOR-TRAIN"

AN ELECTRIC TRAIN & POWER MAKER

A NEW TYPE OF RAILWAY CAR IN USE ON THE GREAT WESTERN RAILWAY





TWO VIEWS OF THE ENGINE AND DYNAMO WORKED ON THE PETROL-ELECTRIC SYSTEM

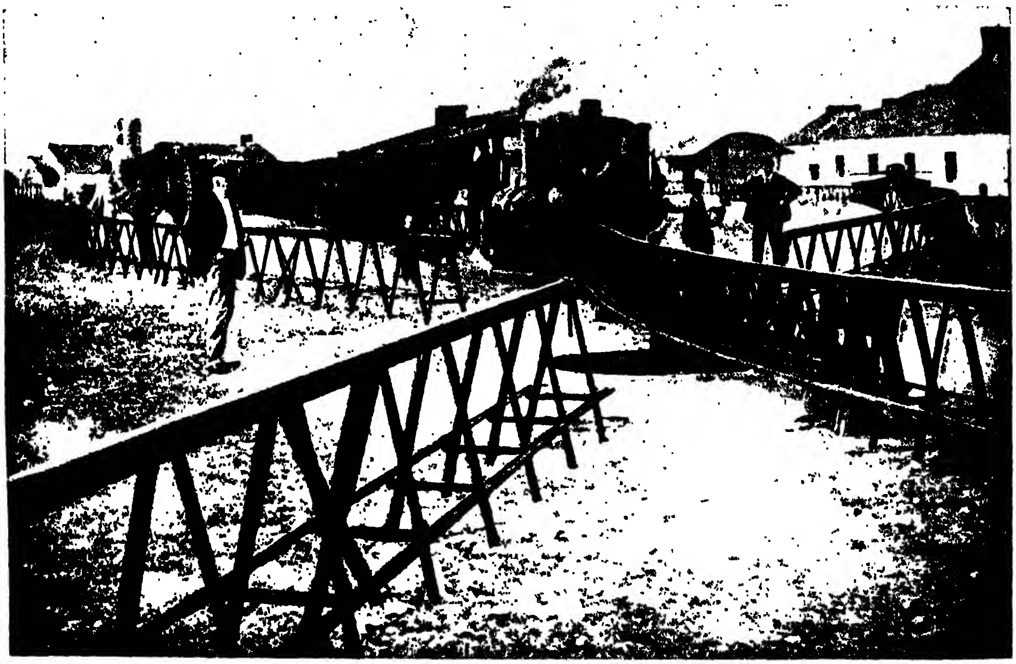
INTERIOR OF THE COACH OF A PETROL-ELECTRIC CAR RUNNING BETWEEN WINDSOR AND SLOUGH

system as soon as he has taken out all his patents, and protected throughout the civilised world the results of his last and most astonishing experiments. This, however, will not be for some months after this is written. So, meanwhile, our readers must be content with a preliminary sketch of these features of the wonderful mono-rail which have already been patented.

In itself the principle of the mono-rail is not new. The single rail system seems to have been first devised by M. Charles Lartigue, a French engineer, who was working in Algeria where an ordinary two-rail track is often blocked by heavy sand-storms. He is said to have derived the idea of balancing trucks over a single rail, from seeing caravans of camels laden on each flank with large bags. In the Lartigue system the single rail is raised and carried on the summit of an A-shaped track. The car has a hollowed channel running underneath that allows it to hang half on either side of the line. The wheels that carry and drive the car are placed in the hollow running down the middle. M. Lartigue used mules as tractive power.

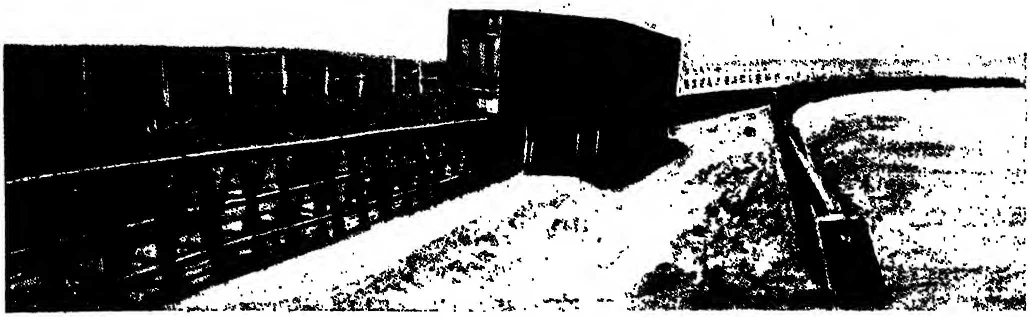
In 1886, however, Mr. F. B. Behr experimented in Tothill Fields, Westminster, with a mono-railway of the same sort, in which steam-power was used. The experiments were so successful that Mr. Behr constructed a mono-rail in Kerry between Listowel and Ballybunion. The line was opened early in 1888, and it works in a satisfactory manner. The single rail is carried five feet above the ground on trestles, and on either side of it the carriages are suspended saddle fashion in two halves. A few years ago a scheme for a high-speed mono-railway of this kind was almost put into operation between Manchester and Liverpool. It would have connected the two cities with a service of trains running at about one hundred and ten miles an hour.

Now, however, the Lartigue mono-rail seems to be eclipsed by the more ingenious invention of Mr. Louis Brennan. We believe that Mr. Brennan was originally a watchmaker, working in Australia. Many years ago he devised a new torpedo, the rights of which were purchased by the British Government, Mr. Brennan himself being appointed to a position of authority at Chatham Dockyard. The Australian inventor has the gift of taking some simple and well-known curiosity of mechanical science and putting it to a marvellous use. In his mono-rail he has performed an apparent miracle by using a scientific toy, the gyroscope, in which only a few mathematicians had hitherto been interested. The gyroscope is a development of the spinning-top.



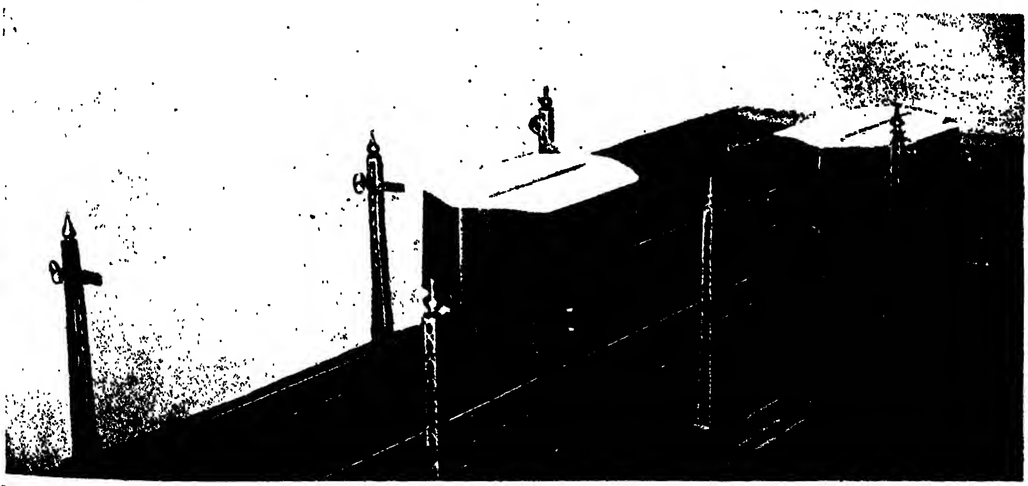
THE BEHR MONO-RAIL BETWEEN LISTOWEL AND BALLYBUNION, IN KERRY, IRELAND

A very curious kind of top can be made by fixing the string to the head of the top by means of a swivel. This swivel-headed top is quite a common children's toy, but when it is spun it acts in a very remarkable manner, that fascinates astronomers and students of physical science. The direction in which it turns round on its point is contrary to the direction of the curve it makes on the ground. That is to say, while the top itself is twirling to the right, the toe of the top will move to the left. This movement, contrary to the spin of rotation, is called "precession." The fact that the earth is a top with this contrary double movement, spinning in one direction, but curving forward round the sun with an opposite motion, has led several mathematicians to go very deeply into the theory of the spinning-top.



EXPERIMENTAL MONO-RAIL AT BRUSSELS, WHERE A SPEED OF NINETY MILES WAS ATTAINED

The study of rotation, however, necessitated the invention of new instruments, and the spinning-top was developed into the gyroscope. In its simplest form, the gyroscope consists of a wheel spinning round an axle. The case in which the axle and wheel are fixed is mounted on an outer frame in such a way that the spinning wheel is able to perform two movements. It can spin round its axle in the ordinary way, and it can also swing sideways to the left or right. This sideways movement is a motion of precession, somewhat like the curve that the earth or a swivel-headed top makes contrary to its rotation of spin. Men of science have built up an astonishing theory of the structure of the universe by studying the motions of a gyroscope. It was this instrument that Lord Kelvin used in working out his theory that solid matter was not



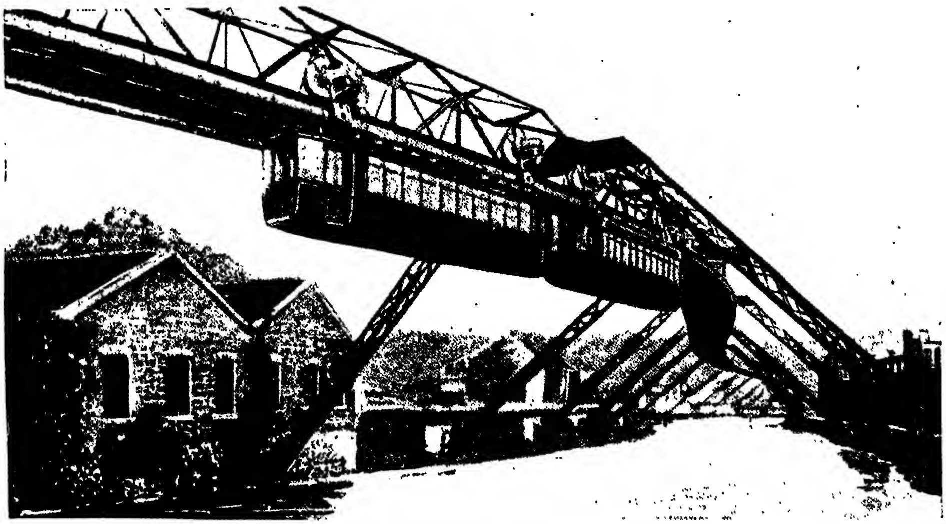
MODEL OF A MONO-RAIL SYSTEM PLANNED FOR A LINE BETWEEN LIVERPOOL AND MANCHESTER, TO RUN AT A SPEED OF 120 MILES AN HOUR

really solid, but composed of minute whirlpools of energy.

What interested Mr. Brennan, however, was the fact that a spinning gyroscope responds in an extraordinary, peculiar way to outside pressure. If the instrument is placed on a table, with the wheels spinning, and the table is tilted, the gyroscope refuses to answer to the tilt. Instead of swinging over to the lower level, the wheel "precesses." Suppose the table is slightly tilted to the right. Anything except a gyroscope would topple over in the same direction. What happens is that the gyroscopic wheel twists sideways, its front end to the right and its rear end to the left. Moreover, the end of its axle rises, absolutely contrary to the downward pressure of the tilting table. It transforms a downward movement into an upward thrust. In short, the gyroscope appears to defy all the recognised laws of gravity.

It will thus easily be seen that the gyroscope is an admirable means of maintaining automatic stability. This was the feature of the wonderful little instrument which attracted the attention of Mr. Brennan, and gave him the idea of a new and much cheaper kind of train, which could be run at one hundred and thirty miles an hour on a single rail, with more safety than an ordinary express can be run on a double rail. Mr. Brennan does not need to build his monorail on trestles five feet from the ground. Owing to their automatic balancing, the Brennan cars are able to run on the roughest of ways. While the cost of building an ordinary railway in England is often about £30,000 a mile, the cost of the new monorail, including the cars, is only £1,000 a mile. Moreover, the single rail can be laid down very quickly. The sleepers are only three feet six inches long, and they are placed on the ground about two feet apart, without any ballast.

The rapidity and the cheapness with which a line of this kind can be constructed makes the mono-rail very useful in military operations. So convinced of its usefulness is our War Office that a Government grant has been made to Mr. Brennan to enable him to erect a full-sized experimental line at Gillingham, on the Medway. On this line, a car forty feet in length is constantly being worked and improved. The single series of wheels is placed down the centre line of the car. The wheels differ from those of an ordinary locomotive in that they have two flanges, one on either side, instead of only one flange.

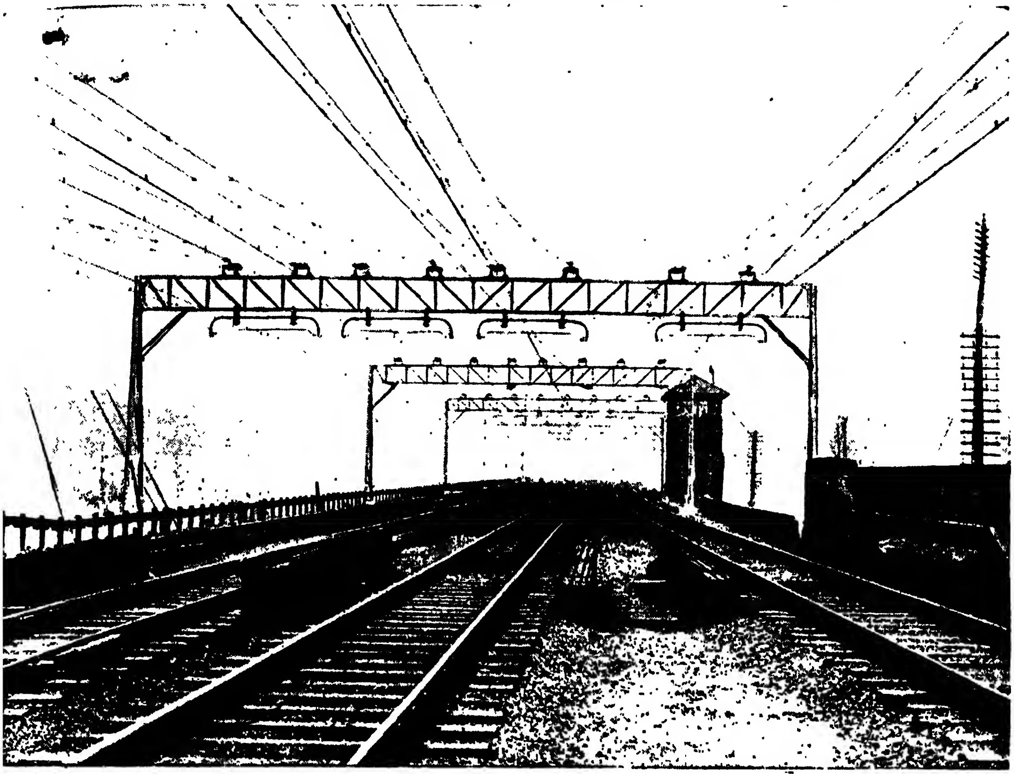


THE MONO-RAIL TRACK OF THE WUPPER VALLEY RAILWAY IN PRUSSIA

This railway runs from Elberfeld to Barmen, is more than eight miles long, and for a considerable part of its course overhangs the River Wupper, as here shown. The trains are suspended from a single rail supported upon steel girders. Each car carries fifty passengers, and with its load weighs fourteen tons.

The motive power used on the train is the same as that with which the Great Western Railway Company is now experimenting. Two petrol engines are attached to electrical dynamos. One engine of eighty-horse-power supplies a current to two motors, each motor being attached to a wheel of the bogie or under-carriage. A smaller petrol engine of twenty-horse-power creates the energy for rotating the gyro-

\N ELECTRIFIED RAILWAY IN LONDON



THE OVERHEAD SYSTEM OF WIRES CARRYING ELECTRICITY FOR A SUBURBAN RAILWAY

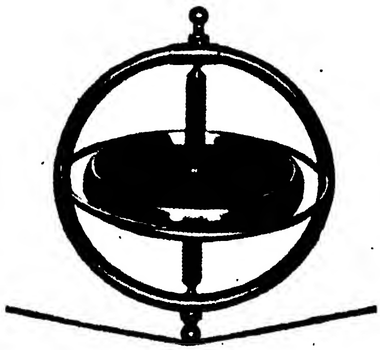
THE NEW TYPE OF ELECTRIC TRAIN ON THE LONDON, BRIGHTON, AND SOUTH COAST RAILWAY

THE SINGLE-RAIL GYROSCOPIC CAR THAT CAN SAFELY DOUBLE THE SPEED OF TRAVEL

A PICTURE-DIAGRAM SHOWING THE MECHANISM AND STYLE OF THE BRENNAN MONO-RAIL CAR, WHICH PROMISES SWIFTER AND CHEAPER TRANSPORT

wheels and working an air-compressor. It also lights the car, and can be used for driving at low speed.

The balancing apparatus consists of two gyro-wheels, each weighing three quarters of a ton. They revolve by electricity three thousand times a minute. For nearly an hour after power is cut off they continue to revolve with sufficient speed to maintain the balance of the car. So no accident to the machinery endangers the lives of the passengers. It is marvellous that two gyro-wheels, weighing together a ton and a half, can be kept efficiently working for an hour after the engine stops. This result is due to the inventive ability of Mr. Brennan. He has devised special bearings which reduce friction to a minimum, and built a vacuum case for the wheels, in which there is no air to impede their movements. The wheels are constructed of white metal, and as they spin they lubricate themselves and force the oil through a series of cooling coils, and then send it back into a reservoir. This reservoir contains a supply of oil sufficient for many months.



THE GYROSCOPE

The two gyro-wheels revolve side by side at the same speed, but in opposite directions. This is necessary for the purpose of turning corners. A single gyro-wheel balances the car only too well — when the train is travelling round a curve, the spinning wheel will not alter the direction of its plane of rotation; it tries to keep the car in a straight line. When, however, two gyro-wheels are used, with contrary spins, their movements in turning a corner balance each other, and leave the train free to turn on the curve. In other respects, the two wheels act as one, and produce a double reaction to any upsetting influence.

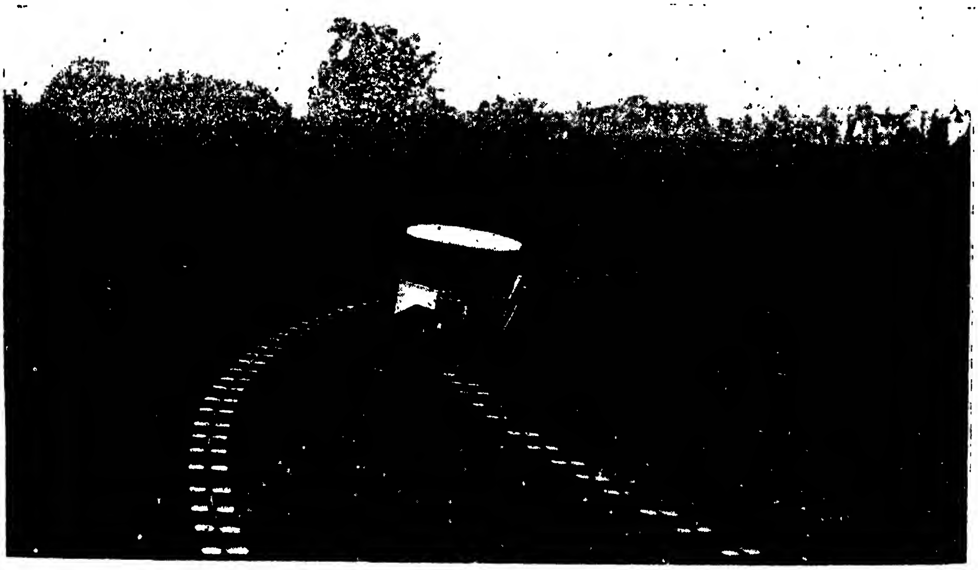
MR LOUIS BRENNAN AND HIS INVENTION

Supposing a strong wind is blowing against the left side of the car. In the ordinary way, the car would topple over. Instead of this happening, the gyro-wheels swing sideways, their front ends to the right and their rear ends to the left. At the same time the right-hand ends of their two axles rise. In rising, they strike against certain pieces of steel which are called guide-plates. These guide-plates perform two actions. In the first place they work, when lifted up under gyroscopic pressure, a compressed-air engine. In the second place, they transmit to the car the pressure which the gyro-wheels exert on them. Mr. Brennan found in the course of his experiments that the pressure of the gyro-wheels was not sufficient to right the car. So, when the axles of the wheels lift, a compressed-air engine is brought into play, and the natural pressure of the gyro-wheels and axles is intensified. The axles press on the guide-plates with very great force, and compel the car to stand up steadily against every overturning tendency.

To put the matter in a simple and picturesque way, the two gyro-wheels are the brain of the car—a brain exquisitely sensitive to the slightest disturbance, and yet endowed with the force of a large number of men. They are a pilot with superhuman energy and superhuman exquisiteness of touch. If a hand-bag is shifted from one side of the carriage to the other, the gyro-wheels feel the alteration of the load, and the two axles move imperceptibly, and just throw a pound or two more pressure against the guide-plates. Under their guidance, sharp, swift corners that would wreck an ordinary train are rounded smoothly and steadily. Some time ago Mr. Brennan exhibited a

small model of his gyroscopic car to the Royal Society. It was wonderful to see the little locomotive guide itself along a single wire stretched six feet above the floor. One man of science stopped the car in mid-air, and swung the wire to and fro violently. But the perfect automatic stability was not disturbed. It was found that the car could be left for hours balancing itself on the wire, with nobody in charge. Until the gyro-wheels ran down, the apparent miracle of stability went on. If, when the car was not running but merely balancing itself, a person pushed against it, the car pushed in opposition. It was just as if an indignant acrobatic animal were resisting an attempt to overturn it.

learn of improvements which Mr. Brennan is effecting in his mono-rail. The new locomotive promises entirely to revolutionise our present means of land travel, and it has taken many years to develop it into a commercial success. It embodies, not a single invention, but a long series of inventions in an entirely new field of engineering. Mr. Brennan has had to consider that the greater part of the civilised world is already covered with doubled-lined railways, in which many thousands of millions of capital have been sunk. There is no room for the costly experiments which the railway engineers seventy years ago were able to carry out. The mono-rail cannot start as the ordinary



THE FIRST GYROSCOPE RAILWAY—MR. BRENNAN'S EXPERIMENTAL MODEL RUNNING IN A FIELD

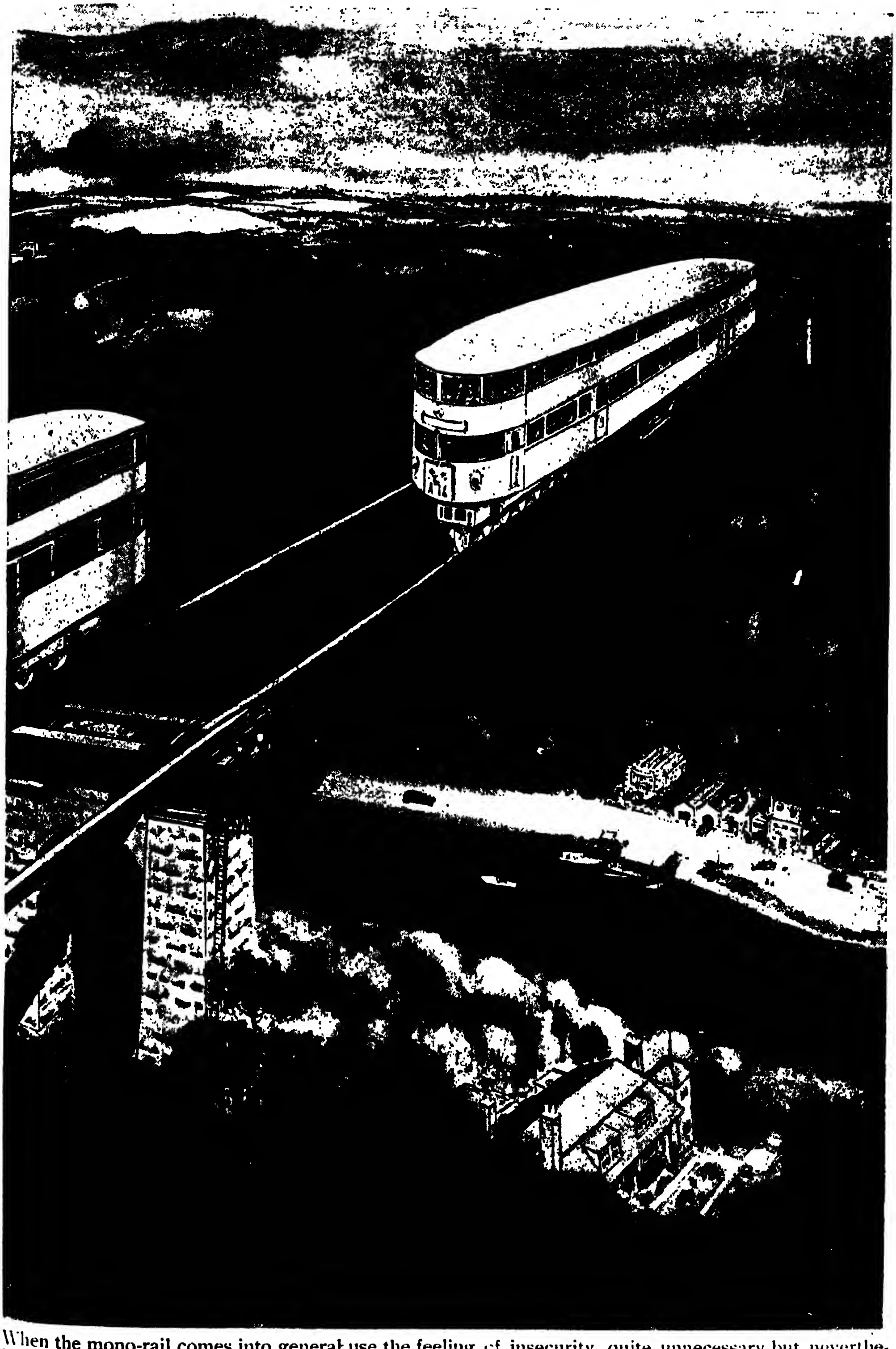
The gyro-wheels weigh only about one-fifteenth of the mass which they keep balanced on wire or a single rail. Thus two wheels, weighing together one and a half tons, will work a car weighing, unloaded, twenty-two tons. The quicker the wheels spin, the smaller the wheels themselves need to be. It is the spin of the wheel that does the work of balancing; and every time the wheels turn sideways and lift their axles to resist an overturning pressure, some of the energy of the spin is exhausted. This, together with the energy lost in frictional heat, is made up by the electric motor, which maintains the rotation of the gyro-wheels.

It is probable that during the year in which this is written (1912) the world may

locomotive and the motor-car started. It must emerge from the inventor's workshop perfect in every detail, and both cheaper and more efficient than its long-established rival.

At present, the mono-rail is in a position similar to that occupied a few years ago by the steam turbine and the Diesel oil engine. Its principle has been thoroughly worked out, and shown to be sound. It has long passed the model stage. With the help of the Government, a real train and a real line have been built, and the mono-rail is now only waiting the working out of the final experiments, in order to effect a profound change in one of the principal forces of modern civilisation. Already the nationalisation of our railways at their

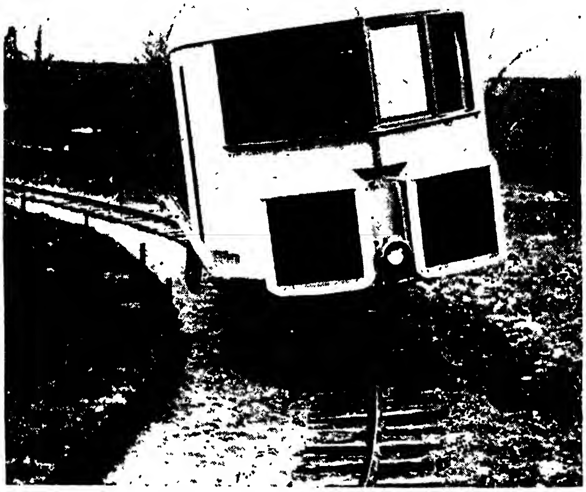
THE AERIAL PASSAGE OF THE MONO-RAIL



When the mono-rail comes into general use the feeling of insecurity, quite unnecessary but nevertheless inevitable, will be felt the strongest where, as is here represented, there are single-rail bridges.

present value is clearly seen to be a mistaken proposal. It would be about as profitable as the nationalisation of the horse-drawn 'bus service on the invention of the motor-'bus. We do not know if the Government has obtained any rights in Mr. Brennan's mono-rail in return for the grant made by the War Office. But if such is the case, the money may prove to be as well spent as that which was invested by the nation in the shares of the Suez Canal.

There can be little doubt that the high-speed railway is destined to become a revolutionising power in our civilisation. Under its influence, the enormous overgrown cities, which are a direct creation of the old, slow locomotives of the nineteenth century, will be broken up and scattered over all the green countryside. Landed property will fall in price in many residential parts of the great towns — a process that has already begun. And, on the other hand, the value of land within a hundred miles of great industrial centres will be increased. Whether this will make for the benefit of the farmer is very questionable. If large tracts of agricultural land acquire a residential value, it may be impossible to farm them at a profit. The result will be that the English people will become still more dependent on Colonial and foreign wheatfields.



THE BRENNAN MONO-RAIL CAR ROUNDING A CURVE AT A SPEED OF TWENTY MILES AN HOUR

It is to be hoped, however, that a quicker and cheaper transit of goods will make market-gardening throughout the United Kingdom a more lucrative pursuit. New scientific methods of culture, combined with well-managed schemes of co-operation and lower carriage rates, ought to enable the market-gardeners of the future to survive and flourish amid all the changes in our national life brought about by the high-speed railway. So far as the future lines of the development of the land of the country can be foreseen, it would appear that a larger and looser kind of Garden City will spread for about a hundred and fifty miles round the centres of industry—a Garden City with wide pasture grounds, large market-gardens, and perhaps poultry-farms, all interspersed with the healthy and picturesque dwelling-places of millions of emigrants from the huge cities. The cities themselves will resemble the real City of London at the present day—crowded in working hours, but strangely empty and silent at night and at week-ends.

There will then be no need for the working classes to pass all their existence in the shadow of factory shafts and mill chimneys. They will be able to resume the healthy ways of life of their ancestors, and combine with their industrial pursuits the invigorating and profitable culture of small-holdings and allotments.

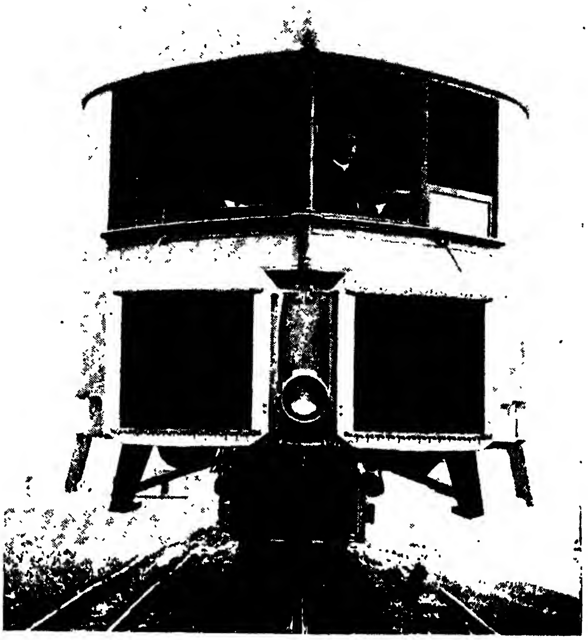
Here is a time-table drawn up on the assumption that mono-railways, with the speed of one hundred and thirty miles an hour, will eventually spread over the British Isles. A man leaving London at 10 a.m. would reach:

Brighton ..	50	miles away, at	10.23 a.m.
Portsmouth	60	,, ,, ,,	10.28 a.m.
Birmingham	113	,, ,, ,,	10.52 a.m.
Leeds ..	188	,, ,, ,,	11.27 a.m.
Liverpool..	202	,, ,, ,,	11.33 a.m.
Holyhead	262	,, ,, ,,	12. 1 p.m.
Edinburgh	400	,, ,, ,,	1. 5 p.m.
Aberdeen	540	,, ,, ,,	2.10 p.m.

If the Channel ferry were constructed, a trip to France on a Saturday afternoon would be as easy and as rapid as an afternoon trip to Kew now is to many Londoners. Paris would only be a little more than a

two hours' journey away from London, and every week-end the pleasant land of Kent would attract thousands of French week-enders, while a larger crowd of English folk would wander amid the orchards of Picardy.

On the whole, therefore, the high-speed railway, smooth-running, comfortable, and safe, will undo much of the harm done by the thirty-miles-an-hour train of the last century. It will take the people away from the shadowed, smoky, and poisoned air of the huge industrial city, and set them in green fields and clear sunlight, open to the fresh, sweet winds of the earth. Many of the diseases which attack and undermine the strength of our urban population will be mitigated, and, with the advance of medical science, conquered. If only some wise statesman is at hand to direct the course of events, the slum will become a nightmare of the past.



A MARVEL OF BALANCE—THE BRENNAN MONO-RAIL CAR STANDING STILL

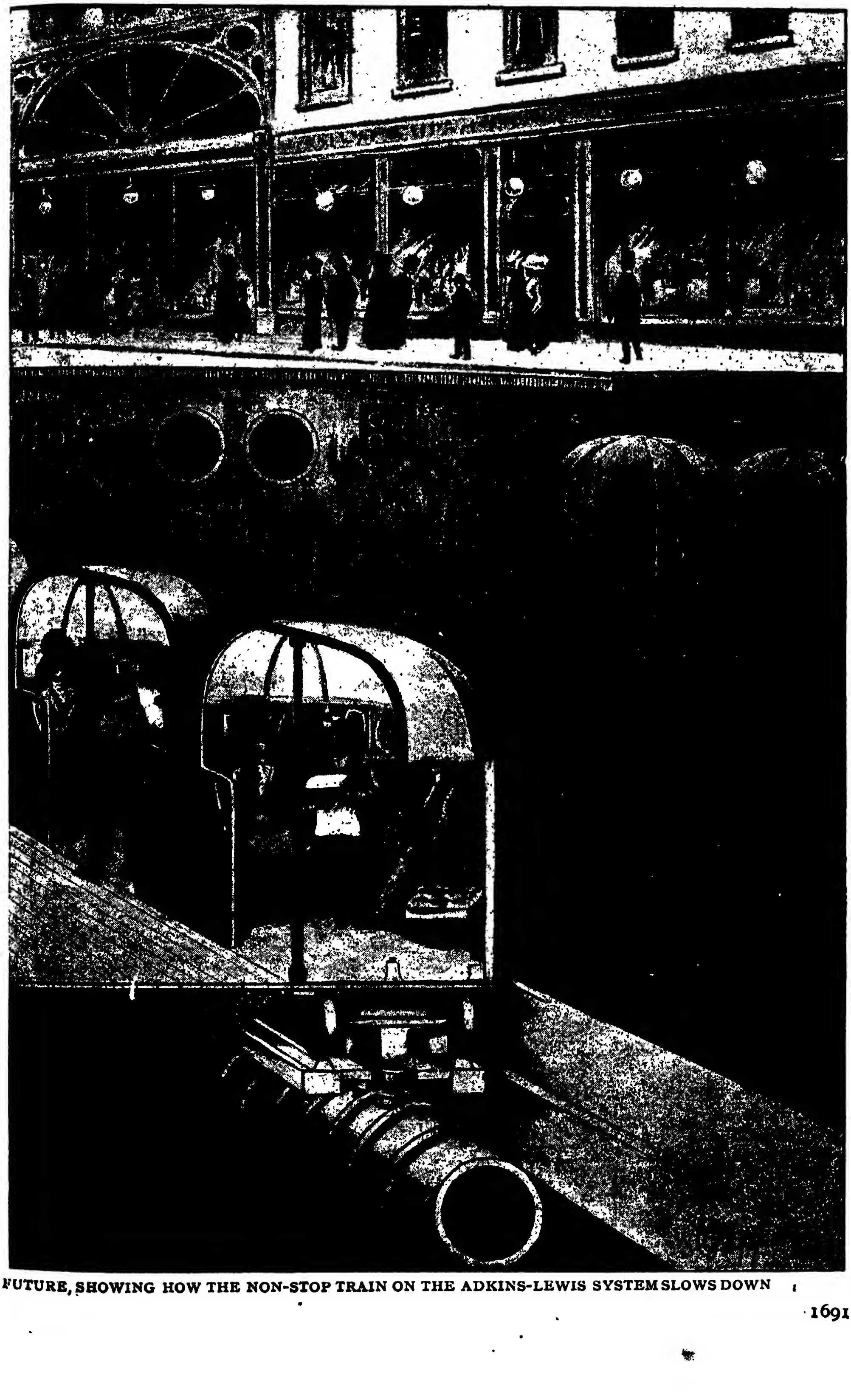
Turning now to the problem of urban traffic, we have to consider what improvements can be effected in the underground electric railways, and the electric road-tramways, which in the last few years have produced some remarkable changes in the life of the London middle classes. The electric tubes and the electric trams have already started that exodus of urban population which promises to empty the towns into the country. Both the artisan classes and the middle classes are beginning to answer to the larger suburban movement created by the new means of electric traction. Cheaper houses in more pleasant surroundings are drawing hundreds of thousands of city workers to the edge of the green fields.

Though in many places there obtains the same greedy, muddling waste of splendid opportunities which led William Morris to say, "God made the country, man the town, and the devil the suburbs," yet there are signs that a finer, nobler spirit of organisation is now at work. What has been done in Hampstead Garden Suburb, for instance, is bound to have at least a great effect in the development of the new towns which are springing up some miles beyond our great cities. The fact that Hampstead Garden Suburb is a financial as well as an architectural and civic success is compelling owners of large estates ripe for building purposes to use a little foreseeing control in the laying out of their property.

The electric train and the electric tram have done some good in starting the emigration from the over-crowded cities. It is, however, far from certain that the present trains and trams will increase in range and number. They are not among the railways of the future. For at the last meeting of the British Association, and subsequently at the Royal Society of Arts, a new means of urban and suburban locomotion was discussed, which has attracted the attention of the whole civilised world. It is known as the Adkins-Lewis system of continuous transit, and has already won the approval and support of the several eminent engineers who have been given an opportunity to investigate the designs in detail. In some respects it is a modification of the idea of a moving platform, but it contains some strikingly original features. The great thing in its favour is its extraordinary simplicity and its wonderful cheapness. It costs less than half the expense of building the more recent tube railways, and the gross operating expenses are only about one-fifth.

A PICTURE-DIAGRAM OF A STATION ON THE PROBABLE UNDERGROUND RAILWAY OF THE

CONTINUOUS TRANSIT SYSTEM WORKS



FUTURE, SHOWING HOW THE NON-STOP TRAIN ON THE ADKINS-LEWIS SYSTEM SLOWS DOWN

Throughout the length of the railway line of the Adkins-Lewis system there extends a screw that is driven at a constant speed by electric motors. The screw is in the same position in the centre of the line as the live rail seen in the tubes. The thread of the screw is not of constant pitch. It is very close in the stations, and it gradually opens out in the intervening length. As the screw turns, its thread acts on rollers fixed on the under side of each car. The rollers engage with the revolving thread, and travel along the screw. So the car moves forward, the speed varying with the pitch of the spiral thread with which the rollers are working. In the stations the screw propels the train along speed during the journey. The quickening of the cars, however, is quite gradual. No inconvenience is felt in reaching the full speed. Indeed, on the experimental track which has been constructed at Ipswich a passenger never experiences, when standing upright, that tendency to fall over with which all straphangers on the tubes are sadly acquainted. In the continuous-service system passengers are handled in streams, instead of in congregations. By this means much greater capacity and comfort can be secured.

Another advantage is that the stations will be nearer together. In ordinary tube railways it does not pay to have stations less than half a mile apart. This is the

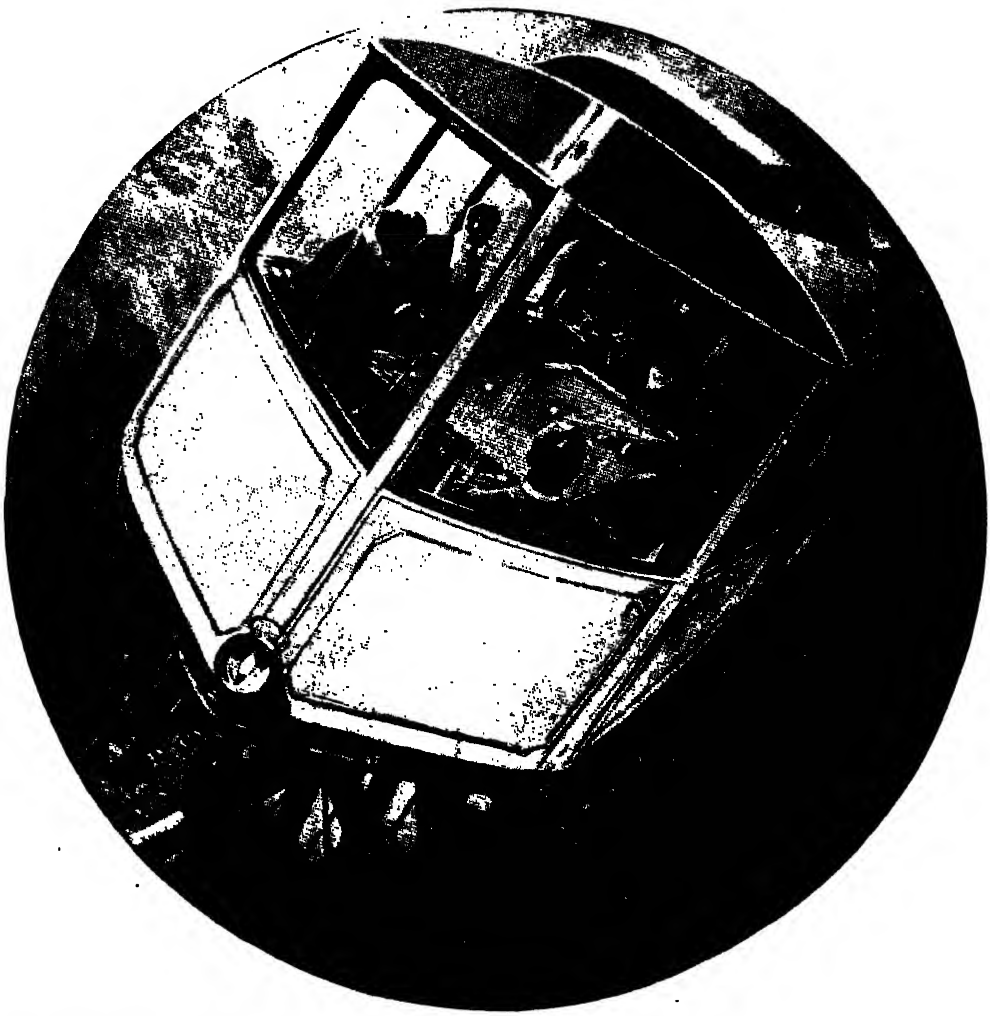
THE MONO-RAIL CAR TRAVELLING TWENTY MILES AN HOUR WITH A LOAD OF PASSENGERS

at two and a half miles an hour, at which speed the vast majority of passengers will undoubtedly be able to mount and dismount, but between the stations the speed increases to twenty-four miles an hour. The coaches consist of light cars, seating only eight or ten people, and entirely open one side. The passengers board and leave them while they are in very slow motion through the station. The coaches are so arranged on the line that they are always packed close together at the station and spread out widely in the intervals. Thus cars are always to be found in a station ready for passengers. The service is as continuous as a moving platform, but the ingenious changes in the thread of the screw permit the attainment of a highly satisfactory economic limit for the present intermittent-service system. When distances between stations are great the electric energy put into the line is almost entirely employed in overcoming train resistance. When, however, the stations are as little as half a mile apart, it takes just about as much energy to get the train up to speed as it does to propel it from one stopping place to another. Thus only half the power put into the motors is usefully employed. The other half is utterly wasted in the grinding of brake-blocks, wheels, and rails, in consequence of which both the permanent way and the rolling stock suffer heavy and costly depreciation.

In the continuous service on the Adkins-Lewis system the stations are designed a

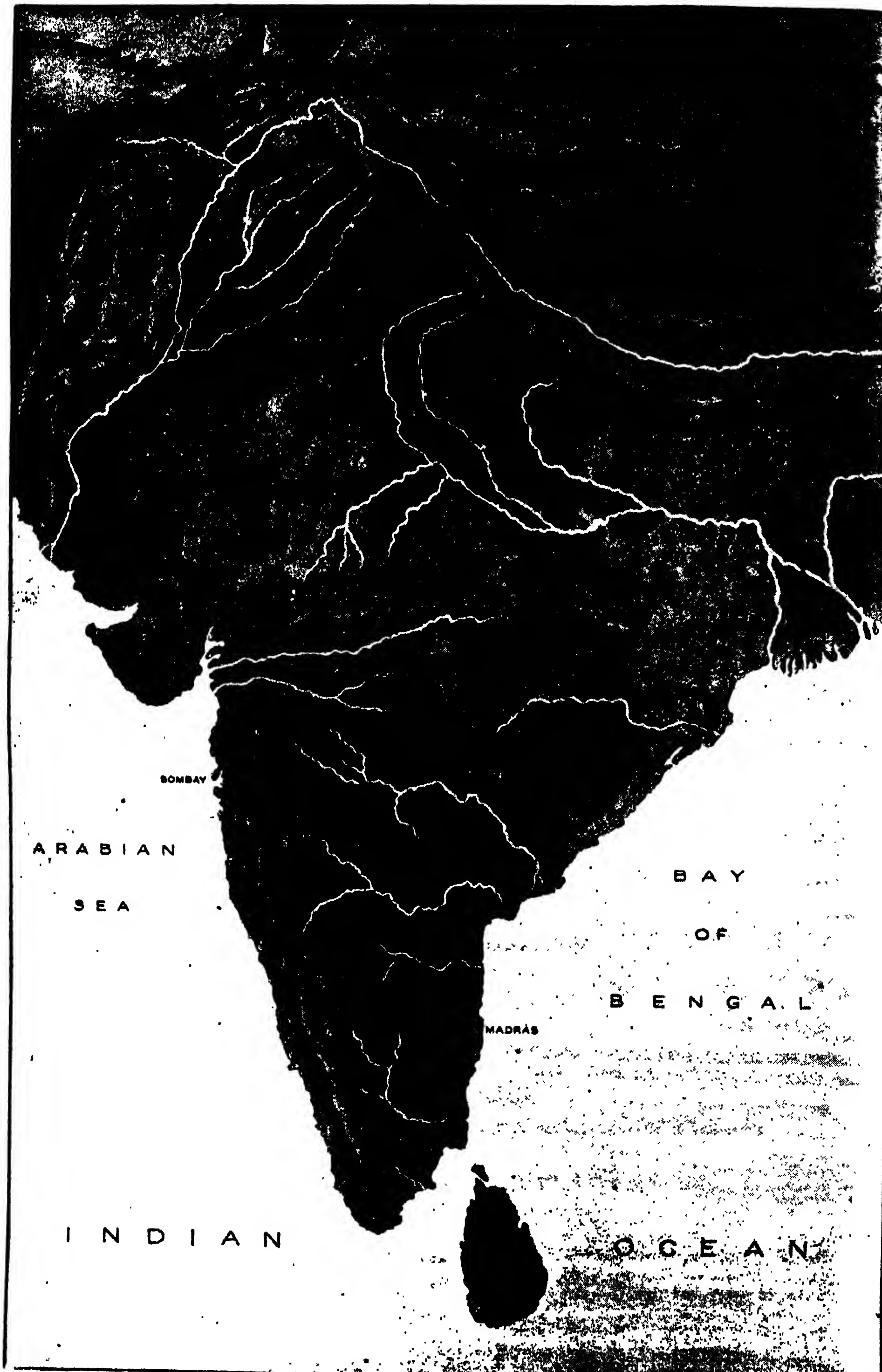
quarter of a mile apart. Instead of wasting power, a stopping car would help to turn the screw around, and so feed its energy back into the system. Preliminary tests show that as much as eighty per cent. of the energy is recoverable in this way. The wear on the rolling stock has been found to be much less than in the ordinary tube; and Mr. Yorath Lewis submits that the wear on the edges of the screw and on its pair of engaging rollers will be so slight that little repair will be needed for many years. It is claimed that the continuous-service system could be worked with only one-third of the energy now found to be necessary in train practice. But as with this one-third energy double the capacity and twice as many stations would be provided, the continuous train would be almost one-sixth as cheap in power as the ordinary tube. It is, of course, possible that this may be too sanguine an estimate. But even if the continuous service is only half as cheap as the modern electric tube, there must be a great future before it.

Certainly a system where one can step down to a station and always find waiting a train which will go swiftly and comfortably through a well-lighted tube seems the nearest approach to the ideal solution of the problem of urban passenger traffic. With the stations only a quarter of a mile apart there will be no reason for the existence of the electric tram or motor-'bus that shake the houses by which they pass, and make the road crowded, perilous, and very often ugly.



THE STEADYING POWER OF THE GYROSCOPE—A GAME OF BILLIARDS ON AN INCLINED TABLE

WHERE SCIENCE CORRECTS RAINFALL



A map of India drawn to show how the rivers—marked white—are utilised to irrigate, by means of a network of canals, the areas here marked black in contrast with the rest of the country

MAKING THE DESERT BLOOM

The Enormous and Beneficent Irrigation Works of India that Hold Up Its Plentiful Water

SAVING MILLIONS OF ACRES AND LIVES

As often as one's thoughts revert to the vastness and magnificence of our Indian Empire the opening paragraph of Macaulay's immortal essay on Lord Clive comes to mind: "Though every schoolboy knows who imprisoned Montezuma," etc., not one in ten among educated men knows even the most salient facts in the story of the conquest of India, the inhabitants of which were ten times as numerous as those whom the Spaniards vanquished. Over and over again, too, the House of Commons and the English nation as a whole have been reproached for their indifference to the affairs of the people who inhabit the vast territories of our dependency in the East. If this is true of the political history of that vast country it is equally so in relation to the engineering works which are being carried out unceasingly there, and to which the newspapers hardly ever give so much as an obscure paragraph. For generations British India has been indebted far more to the labours of the civil engineers than to those of any other body of men whatever. Theirs: "To scatter plenty o'er a smiling land and read their history in a nation's eyes."

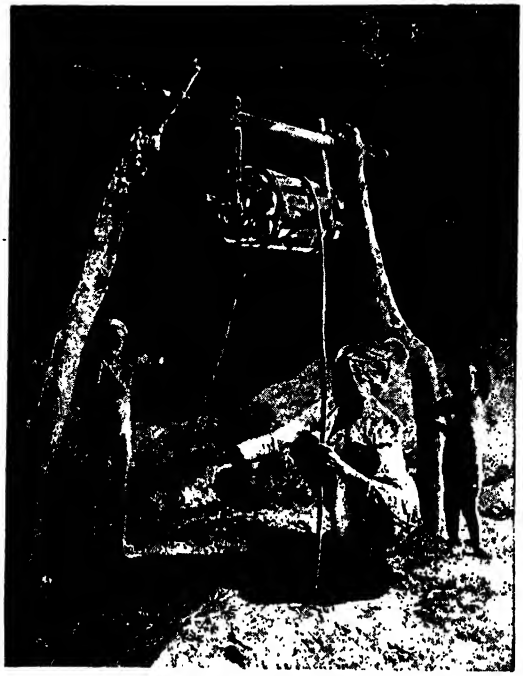
India, including the Native States, occupies an area of 1,773,000 square miles, about equal to the whole of the European countries, omitting Russia, and it has a population of 316,000,000, or seven times as great as that of the United Kingdom. The people speak a hundred and forty-seven different vernacular languages. This vast field has been occupied by a corps of engineers subjugating and directing the resources of Nature for the benefit of a population equalling more than one-fourth of the human race.

Famines in India are the dread scourges which the work of the engineers is designed to avert or diminish, first by the construction of irrigation works, and second of railways. The first wring smiling harvests from a reluctant soil, the second transport the produce from the more highly favoured to the less fruitful districts. Forty-eight years ago, in the terrible famine of Orissa, a million persons, or one-fourth of the total population of the province, perished of starvation, notwithstanding that one and a half millions sterling had been expended on relief works. The ghastly terror of such a visitation is well-nigh inconceivable. By contrast with it even the Black Death and the Plague appear to lose something of their awfulness and magnitude. In 1877–8 the death-rate through famine in India was 5¼ millions over that in normal years, while the birth-rate was less by two millions. During the five years 1873–8 the money spent in relief works amounted to 16½ millions sterling.

As the years roll on, men known only among their professional brethren quietly fight the scourge of famine there; and India, the babble of agitators notwithstanding, is now enjoying a vastly larger share of prosperity and immunity from starvation than she ever knew under even the best of her native rulers. This is due largely to the great State irrigation works carried out in the Presidencies and the Local Governments and Administrations. In these works up to the present time about £38,000,000 have been sunk, and by them 22½ million acres are rendered productive. Private works total to more. And it is not a question of making two blades of corn grow where but one grew before, but of growing corn and rice and sugar where, without irrigation, the land would be a desert.

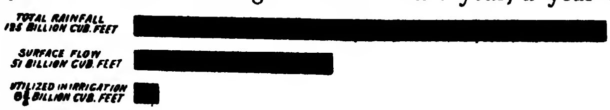
If we note that 65 per cent. of the population of India is engaged in agriculture, the importance of irrigation to those living where droughts are perennial evils may be

grasped. The Indian Government has a magnificent record of good work well done in this direction alone, apart from other works, such as railways, bridges, and roads, of which travelled folk know more. Millions of money have been sunk in order to avert the periodical famines that have ever been the curse of India, and these millions almost all return good dividends—handsome ones in many instances. The average is 6½ per cent., while the cultivators of the soil receive good returns on their rents for water. Districts as large as English counties are thus saved from drought, enriched by the waters dammed and stored in the rainy seasons, for some of these districts would otherwise be under flood during one portion of the year, and parched during the remainder.



AN INDIAN PEASANT IRRIGATING HIS RICEFIELDS FROM A ROUGH WELL

The greater portion of the rainfall occurs during the period of the South-West Monsoon, between June and October. Only in the South-Eastern portion of the Peninsula does the period of heaviest rainfall coincide with the period of the North-East Monsoon, from October to December. The Central Provinces, Berar and Haidarabad, receive some showers, small in amount, during this season. Through the hot season, from March to May or June, practically no rain falls in Bengal and North-Western India, but thunderstorms occur in Bengal and in the hills of Northern India without the usual downpour.



PROPORTION OF IRRIGATION TO RAINFALL IN INDIA

The problems unceasingly confronting the men who scheme the irrigation works in India are extremely perplexing. Over that enormous extent of country all kinds of irregular conditions exist, the principal of which are the extremely variable character of the rainfall, the character of the soil, and the nature of the crops raised. Take first the rainfall, for that is the principal thing.

The average over the whole of India is 42 inches in the year. That is, 42 inches would be the depth of rain-water if it were distributed equally over the entire country, and this average has never varied by more than 7 inches in any one year. So there is not much fluctuation from that point of view. But in some districts the annual rainfall is only one-fourth of this; in others it is more than double. In comparing localities, the extremes are represented by 5 inches in some cases and by nearly 500 inches in others. An excessive rainfall is responsible for many of the engineering difficulties. The normal conditions for any given district are much more easily anticipated and provided for than the abnormal years of drought, which occur with an average frequency that varies very widely in different parts of the Peninsula.

It is always the abnormal conditions which put the irrigation works to the severest tests. Thus, in one year from the catchment or rain-collecting area serving the Astiti tank, the run-off of the water was only 1·9 per cent of the total precipitation. In the next year, a year of heavy rainfall, it was 24·5 per cent. In another case, in the Mahanadi catchment area, with a rainfall of 44·1 inches, the run-off was 5·1 per cent. The next year, with a rainfall of 59·7 in., the run-off was 36·1 per cent. Neither, again, is the run-off at all proportional to the rainfall, but it increases with the torrential character of the rain, even though the total fall for the season may be deficient.

Further, the rainfall of any district

cannot be regarded apart from the nature of the soils. These comprise, in some districts, vast alluvial tracts of yellow loam, clay, and sands; in others, the black cotton soils of the Deccan trap, where cotton is mostly grown; in others, again, the crystalline and sandstone formations occur. Crops, too, differ greatly in the extent of their need of irrigation. Cotton does not ordinarily require any irrigation, and very little even in years of drought. Barley only wants irrigation in a dry year, but wheat requires a good supply, as does sugar-cane, and rice takes most of all. It is estimated that 1,000,000 cubic ft. of water are required to irrigate six or eight acres of ricefield, and a third of that quantity for wheat. Other crops are millet, jute, gingelly, indigo, linseed; some of these are spring crops, others autumn, and all require suitable soils and varying amounts of irrigation.

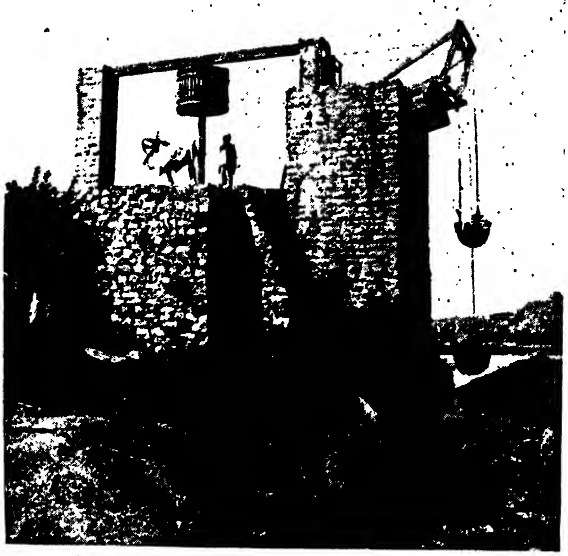
Then, again, besides the character of the soil and crops, the natural dispositions of the land determine what kind of irrigation must be adopted. There are three great systems: canals, tanks, and wells, with some other sources not classed. In the vast alluvial plains traversed by the rivers that rise in the Himalayas and in the Western Ghats, canals and wells are by far the principal sources of distribution. All the great canal systems of India occur in these tracts, while the tanks form a very insignificant proportion. On the other hand, the channels of the rivers that rise in the Western Ghats and pass through the crystalline tracts of country are too deep, and their gradients too small, to admit of use for irrigation in the vast plains beyond. Here, therefore, the tanks form the principal supply, collecting and storing the rainfall from the area surrounding them. These last districts include nearly the whole of Peninsular India outside the area of the Deccan trap; that is, they comprise nearly the whole of the Madras Presidency, the State of Mysore, half of Haidarabad, two-thirds of the Central Provinces, portions of Orissa,

BULLOCKS DRIVEN DOWN AN INCLINE TO HAUL UP WATER FOR IRRIGATION

and some portions of Bengal, of Central India, and Rajputana.

In 1903 the Irrigation Commission estimated that the total area irrigated in the Indian Empire, by State and by private works of all kinds, was 53 million acres, out of 297,000,000 annually sown. Of these, 19 million acres were irrigated from canals, 16 millions from wells, 10 millions from tanks, and 8 millions from the "other sources." Of this total, 44,098,000 of acres were irrigated in British India. Of this total, again, 18½ million acres, or 42 per cent., was watered by State works, and 25½ millions, or 58 per cent., from private works. More than half of the latter were wells. Among the private works classed under "other sources" were 5,000,000 acres drawn from private canals, and from water held up in natural depressions and in shallow artificial lakes.

When thinking of canals, those of our own country give no conception of the dimensions and vast ramifications of the canals of India. The main canals are as wide and deep as the largest English rivers. In the whole Indian Empire, as stated, the canals irrigate about 19,000,000 acres. The great Ganges Canal was opened in 1854, at a period when there were no railways within a thousand miles of it. It is, with its distributing channels, 9900 miles long. In 1878 it was supplemented with a second, and these two now irrigate 1,700,000 acres. This vast canal is 200 ft. wide and 10 ft. deep, and it crosses four great torrents. It serves a tract of country distant 360 miles from its head-works. Two rivers, 200 ft. and 300 ft. wide respectively, are carried over it in masonry aqueducts. The canal crosses the Solani valley by an aqueduct and embankment 2¾ miles in length. At this spot 7000 cubic ft. of water pass each second, and the waterway is 170 ft. broad by 12 ft. deep.



PRIMITIVE WATER-LIFT IN HAIDARABAD

The largest irrigation works occur in Northern India. The biggest feeding-canal there was derived from the Chenab in 1889. Its discharge varies between 3000 and 10,500 cubic ft. per second. Ten years after its opening it irrigated 1,829,000 acres, and supported a population of 800,000 immigrants drawn from other parts of India, attracted by the soil fertilised by the canal.

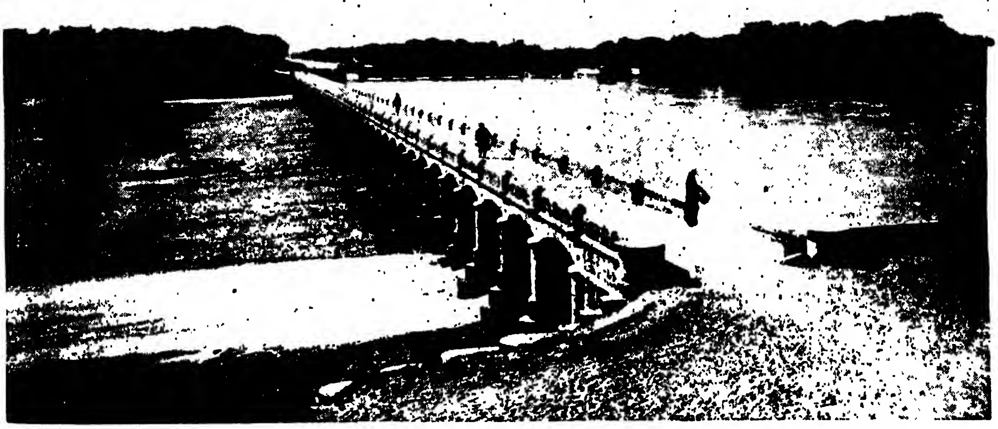
There are two kinds of canals, and two sub-groups of these: the perennial canals, that draw their supplies from a river at all seasons of the year; and the inundation canals, that take water only when a river is in flood. In the former a weir is almost always necessary, and this is one of the most important among the engineering works. In the latter it is not required. At the close of the flood season the inundation canals run dry, and remain so until the next season's rains. The inundation canals have an open head, provided sometimes with a regulator. Examples of these are the Sutlej, the Chenab, and the Indus Canals in the Punjaub, and the Indus Canal in Sind. Many of the perennial irrigation canals serve for navigation.

Canals, are also sub-divided into two other groups—the deltaic and non-deltaic. Both tap and distribute the water from the rivers, but they differ in regard to the distances to which they convey it and the methods they employ.

The deltaic canals are used when the bed of the river that is tapped by them lies but slightly below the level of the surrounding country. No great length of canal is then required, because the water can be distributed by gravitation. Examples of these occur in the Godaveri, Kistna, Cauvery, Penner, and Srivaikuntham systems in the Madras Presidency, and in the Orissa system in Bengal. The other group of canals tap the rivers high up in their courses,

SACRED WATERS OF THE GANGES IN USE

IRRIGATION ENGINEERING IN THE UNITED PROVINCES—THE RANIPUR SUPER-PASSAGE



THE DHANAURI WORKS ON THE GANGES CANAL, LOOKING DOWN STREAM

JUNCTION AND BIFURCATION OF THE GANGES AND LOWER GANGES CANALS AT GOPULPUR

where the bed lies much below the surface, and so they have to bring the water considerable distances to distribute it by gravitation, or sometimes by a moderate lift. Examples of these are the Sirhind, Chenab, and Western Jumna Canals in the Punjaub; and the Ganges, the Agra, and the Eastern Jumna Canals in the United Provinces.

The varying conditions, therefore, which exist in the different parts of India govern the methods of irrigation adopted. Thus, in the Punjaub the rivers rise in the snows of the Himalayas, and, issuing thence, run for enormous distances. They are tapped near their sources, and the canals distribute their waters to the plains of the Punjaub and the country south of the Ganges. In the Madras Presidency, on the contrary, the rivers are tapped nearer their mouths, and the deltaic arrangement is necessary, the waters being stored by dams at the apex of each delta through which it is distributed.

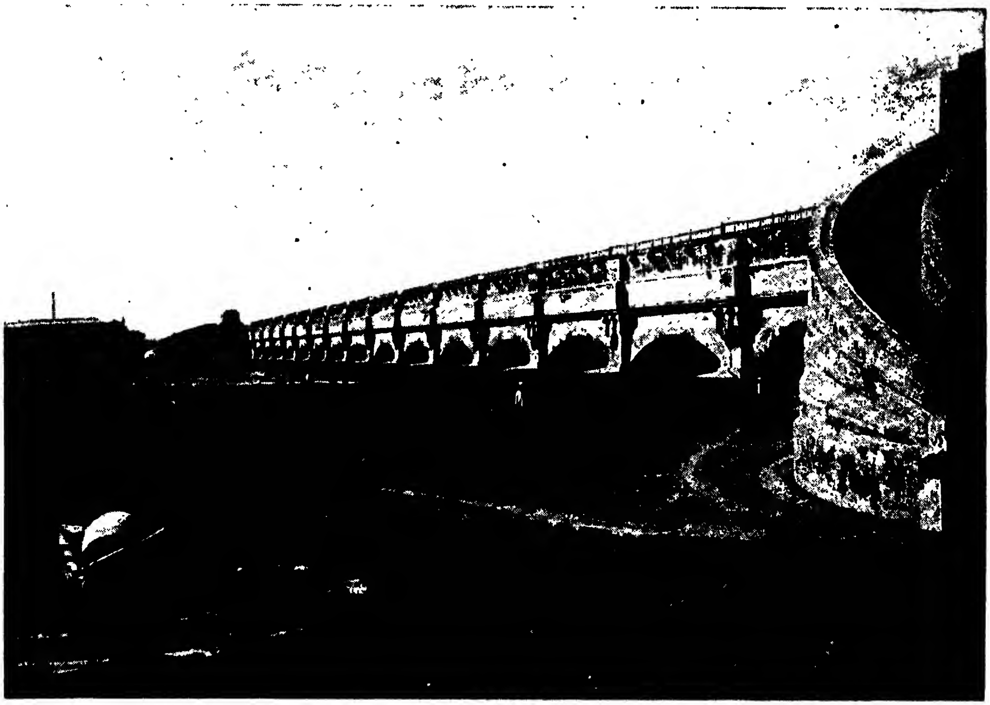
The storage tanks are extremely numerous. Ten million acres in the Indian Empire are irrigated from tanks. These are not tanks in the sense which we attach to the term, but veritable lakes or reservoirs of vast extent. Many of these are natural valleys or gorges, closed by dams, behind which the waters are impounded. There are more than 30,000 of these tanks in the Madras Presidency alone. In Mysore there are 40,000 tanks—three or four to the square mile. These are a source of anxiety, because if a flood happens to burst one, others in the vicinity will be swept away. There is a dam in Mysore 142 ft. high across a valley near Marikanave, to enclose a basin of 2075 square miles, containing, if it were filled, which would not often occur, 30,000,000,000 cubic feet. Yet this is only a "tank," according to Indian reckoning.

A PRIMITIVE IRRIGATION WHEEL

A large portion of the irrigation of Southern India is effected by tanks that are local works, distinct from the great Government schemes, and some of them are works of high antiquity. Earthenware dams are built across natural valleys and depressions, within which the water is collected, and from it distributed. The tanks at Chingleput are 1100 years old, and still irrigate areas of 2000 and 4000 acres respectively. The Grand Anicut dam, ascribed by tradition to the close of the second century, stretched across the Cauvery River, and was in use until 1830. It consisted of a mass of rough stones, was over 1000 feet in length, by from 40 to 60 feet in breadth, and 15 to 18 feet in depth, and its waters irrigated 670,000 acres.

Ruins of ancient irrigation works many centuries old, sometimes overgrown with jungle, exist in various parts of India. The Giant's tank was built in the fifth century, and the old embankments can be traced for fifteen miles in the jungle. There are records of a large tank having been constructed in Ceylon 2400 years ago. In the Madras Presidency, previous to British rule, there were 50,000 large and small tanks in existence, and 30,000 miles of embankments. The Poniari tank had an area of between 60 and 70 square miles, and an embankment 30 miles long. The old earthworks were constructed by natives carrying small baskets of earth on their heads, and trampling them into the embankment. Tanks lose much of their water by evaporation, and by percolation of the water through the soil. In Bombay the average loss due to these causes is four feet of depth a year. In Madras a loss of as much as eight feet has been recorded. This is the reason why the attempt is seldom made to store water for two years.

Wells are very ancient methods of irrigation. There are 16,000,000 acres of irrigation



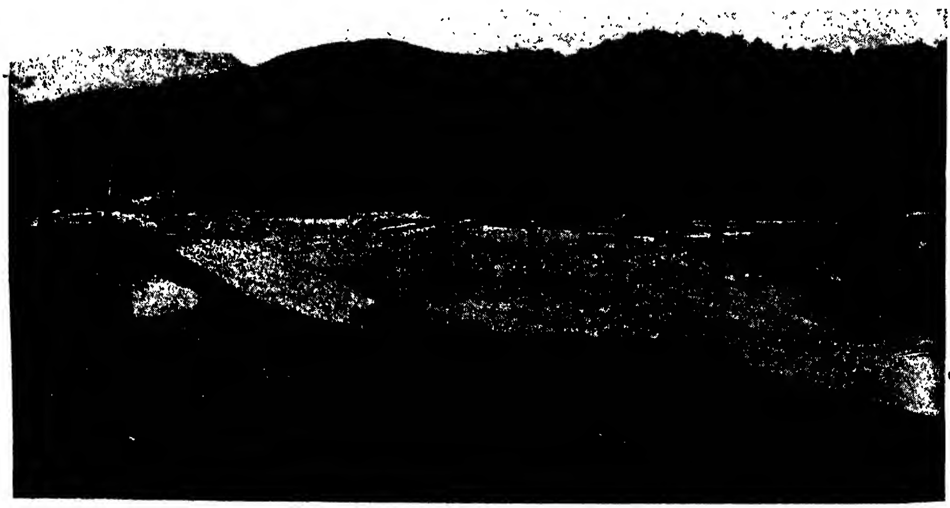
THE SOLANI AQUEDUCT, WHICH CARRIES THE GANGES CANAL OVER THE SOLANI RIVER

THE GREAT SOLANI AQUEDUCT, SIXTY-FIVE YARDS IN WIDTH, AS SEEN FROM ABOVE

by 3½ millions of wells in India. The lifting is done by cattle, to the tune of about the equivalent of 1,000,000 horse-power expended annually. A few years ago the Commission reported that there was room for another 16,000,000 acres of irrigation by wells in India. In British territory alone there are over 2½ millions of wells, irrigating 13,000,000 acres, and 9½ millions of these are found in the alluvial plains of Northern India. Here the subsoil contains an inexhaustible supply of water. This soil is bored through to the clay, which retains the water. In the Punjaub each well irrigates, on an average, eleven acres. Many of these wells are only dug temporarily. A primitive method of irrigation from wells in India is this: a bag is lowered into a deep well, a rope attached to it, which is passed over a pulley, and bullocks haul the bag of water up by running down a hill. The Persian wheel is also turned by oxen. A large well requires four teams of bullocks, with two animals to a team.

The engineering tasks involved in irrigation works include the building of dams or barrages to impound the water in the tanks, and of canals to distribute it. They have to include the regulation of the supply, and its distribution over wide areas. One district may have an annual rainfall of 100 to 200 inches; another, separated from it by a range of hills, may be always short of rain, and famine may be perennial there. Then the first district is made to feed the second by the impounding and controlling of the rains, and the conveyance and distribution of the waters to the thirsty country.

Again, though existing river-courses are pressed into service when possible, the banks of these often have to be trained and canalised to prevent desolation by floods in the rainy season. Natural gorges, when such exist, are utilised to impound or convey water, and vast tanks are formed by taking advantage of natural depressions and valleys, and damming them, and completing Nature's work by the construction of retaining walls where they are necessary.



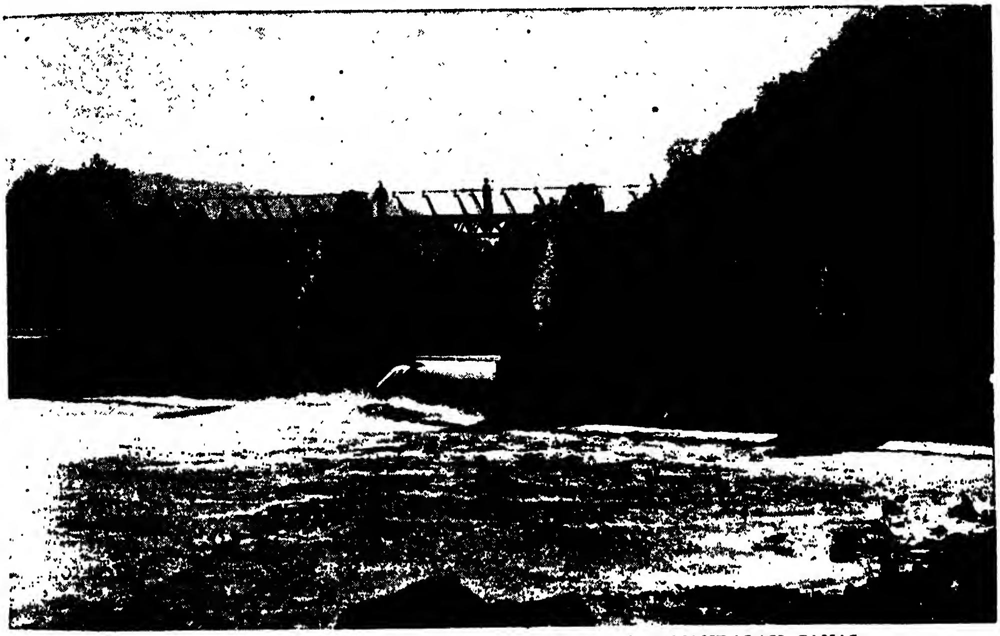
THE HEAD REGULATOR AND UNDER-SLUICES OF THE MANDALAY CANAL, APPROACHING COMPLETION

Much has been heard in recent years of the Nile barrages, and the results in Egyptian irrigation. Little or nothing is ever heard outside engineering circles of the vastly greater works executed in India, carried out, too, in the face of difficulties exceeding any that were encountered at Assouan. Listen to the engineer upon whom devolved the responsibility of constructing the Periyar works, in the Madras Presidency. Here the main dam, 178 ft. above the river-bed, the highest in the world, was built to impound 13,300 millions of cubic feet of water to supply the Madura district, having an area of about 1200 square miles. The dam had to be constructed "in a river subject to violent and sudden floods, in an

uninhabited tract of country, far from a village, very far from any railway, in the middle of a range of hills covered with dense forest and tenanted with wild beasts; where there are no roads, or even paths, and where the commonest necessities of life are unobtainable; where malaria of a malignant type prevails, and where the incessant rain for half a year is a constant deterrent to the importations of labour, and by its effect on the river renders all work in the bed impossible for six months out of the twelve. The character of the environment may be gauged by the fact that for the first two years of construction watchmen, with drums and blazing fires, have had to guard every camp at night against the curiosity of wild elephants, which have constantly visited the works, uprooting milestones, dismembering new masonry, treading down embankments, playing with cement barrels, chewing bags of cement and blacksmiths' bellows, crumpling up zinc sheets, kneeling on iron buckets, and doing everything that mischief could suggest and power perform."

The rivers in India are more erratic than those in Europe, consequent on the periodic floods. They are liable to change their courses, because the silt brought down by the floods fills up the channels and sends the river off sometimes miles away to cut a new channel. The same silt fills up tanks and diminishes their capacity. Huge trees are brought down, damaging the work which the engineers have accomplished. The nearest parallel to this is the floating ice on the Canadian rivers. All this makes the work of construction of dams, tanks, and bridges very troublesome. The foundations often lie in alluvial soil that has to be excavated very deeply. Incidentally, the long railway bridges in India built over these rivers dwarf those thrown over our tiny streams. There are ten railway bridges in India more than three-quarters of a mile long, one more than a mile and a quarter, two more than a mile and a half, and one more than a mile and three-quarters long!

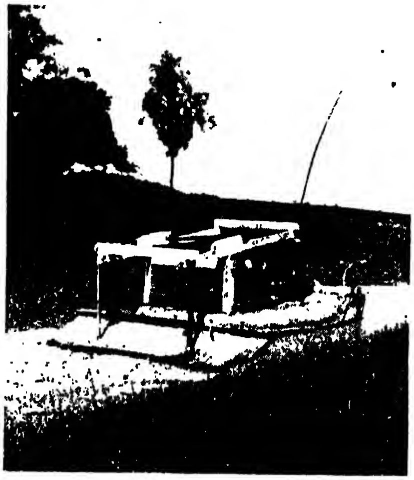
The rain itself is the cause of one of the great obstacles to the construction of irrigation works in India, for the dry season is the only period during which the works can be carried on. And unless the work is done well during that period, the advance of the wet season will bring down volumes of water, to sweep away the greater portion of the first season's work. This heartbreaking experience has often happened. In the Periyar River, for instance, a volume of water of some 4000 cubic feet per second rolls down normally from the end of May to the beginning of December, without taking account of freshets. The highest of these freshets recorded was 127,000 cubic feet per second, or about ten times the discharge of the Thames at Windsor. In January and February the volume diminishes



DOWN-STREAM VIEW OF UNDER-SLUICES ON THE MANDALAY CANAL

to a meagre 400 to 250 feet per second. But even then thunderstorms have to be anticipated. On one particular March night a heavy rain increased the discharge in one hour from 300 cubic feet to 4000 cubic feet per second, entirely destroying a quantity of masonry work that had been constructed.

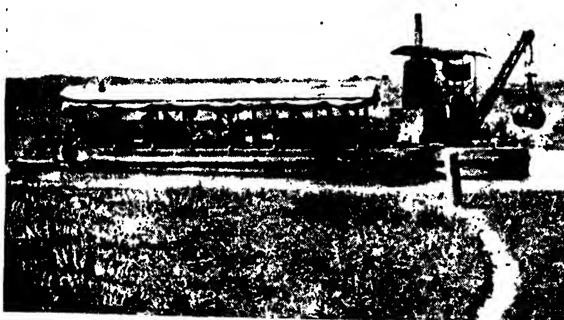
Among recent big schemes are the following: On the western side of the Peninsula the mountains rise abruptly from the sea, and receive a rainfall that amounts to 200 inches annually; and the greater proportion of this water falls into the Indian Ocean, leaving all the country to the east parched, were it not for the irrigation works. It is here that the Periyar scheme diverted the waters of the Periyar River, in Travancore, into the valley of the Vaigai, which flows eastward through the Madura district into the Bay of Bengal. By diverting a constant supply of 1200 feet per second into the Vaigai River, 180,000 acres to the north of the town of Madura are irrigated. This work involved closing the existing course of the river by a solid dam of masonry, the provision for the passage of its waters through the mountain chasm that separates the watershed of the Bay of Bengal from that of the Arabian Sea, and the construction of the works required for the control and distribution of the water for purposes of irrigation in the Madura district.



A SCOURING DAM IN A CHANNEL LEADING TO A LOCK

The chief interest in these works centres in the vast difficulties encountered in carrying out engineering constructions in the hills, an enterprise that occupied about seven years, or, rather, portions of seven years. During April, May and June, when the waters are low, the malaria stops much of the work. When the climate is healthier the rainfall is heavy, and floods are common. Moreover, the site was situated in the hills 3000 feet above sea level, in an uninhabited region covered with dense jungle, and infested with elephants, tigers, and buffaloes. The area of the basin above the dam is about 400 square miles, and the rainfall about 100 inches per annum.

The most imposing piece of work, of course, is the dam for closing the bed of the Periyar. Its thickness at the base is 139 feet, and 12 feet at the top, and with its foundations it absorbed 5,000,000 cubic feet of concrete, composed of 100 parts of broken stone, 30 parts of sand, and 25 parts of hydraulic cement, besides stone for facings. The transport of the materials alone entailed a large plant, a wire-rope tramway included. The dam had to be 178 feet in height across a river having an average discharge of 1200 cubic feet per second, rising in floods to 25,000 cubic feet per second. All had to be done in a jungle twenty miles from the nearest cultivated land, and eighty miles from the nearest railway station. Owing to the unhealthy conditions which existed during three months, and the floods in six months, only three months in the year were available for filling in foundations.



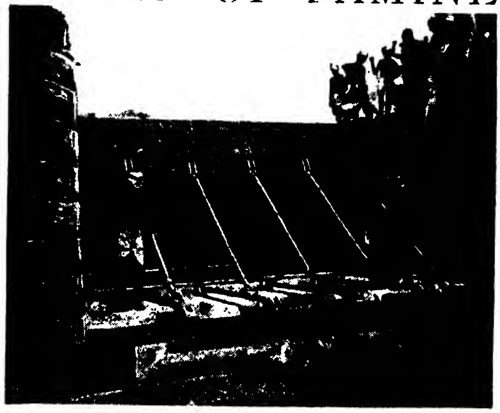
A DREDGER AT WORK IN AN ORISSA CANAL

For the passage of the water through the dividing ridge between the Periyar and the Vaigai a tunnel 5600 feet long had to be driven and the discharge through it might amount to 1800 cubic feet a second. It is 12 feet wide by 7½ feet high, and is bored through solid syenite rock. Drilling and blasting were the means employed, gelatine being the blasting material used.

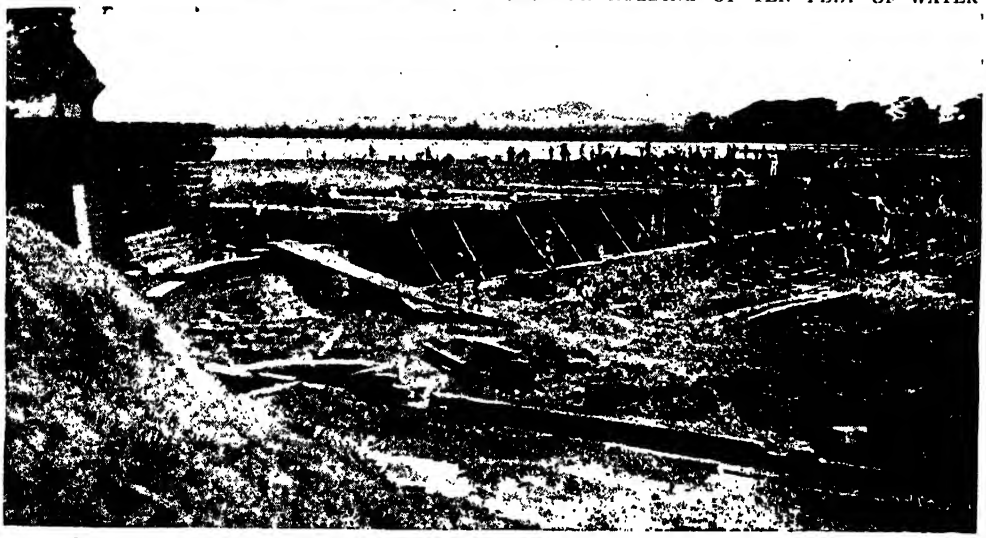
The area of the artificial lake impounded varies with the height of water. It has a

CANAL SCENES IN A LAND OF FAMINE

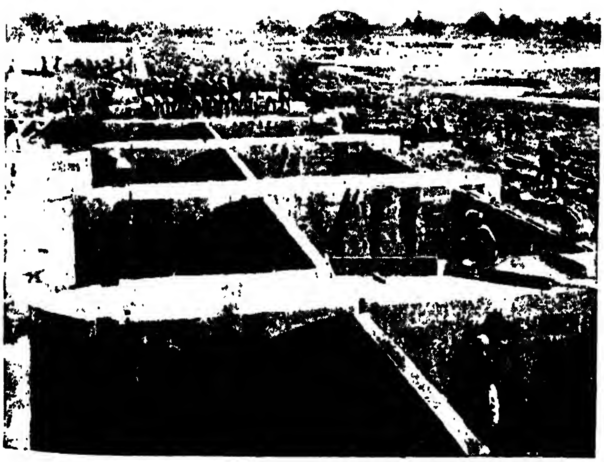
SHUTTERS OPEN ON HYDRAULIC WEIR



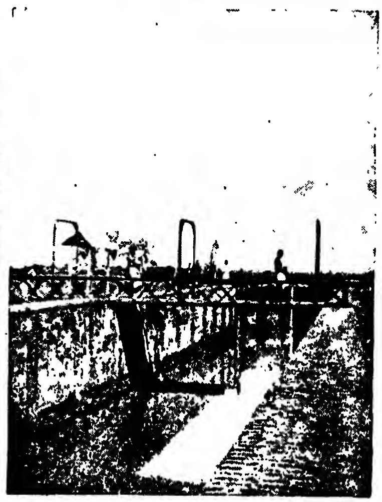
SHUTTER HOLDING UP TEN FEET OF WATER



GENERAL VIEW OF THE ORISSA CANAL WORKS IN COURSE OF CONSTRUCTION



ANOTHER VIEW OF THE ORISSA CANAL WORKS



LOCK ON ORISSA COAST CANAL

The photographs of irrigation works on these pages are reproduced by courtesy of Mr. R. B. Buckley

HOLDING BACK THE WATERS THAT ARE INDIA'S CHIEF INSURANCE AGAINST FAMINE

Lake Fife, near Poona, the second largest storage reservoir in the Bombay Presidency. The hills in view—the Western Ghats—are a comparatively rainy region.

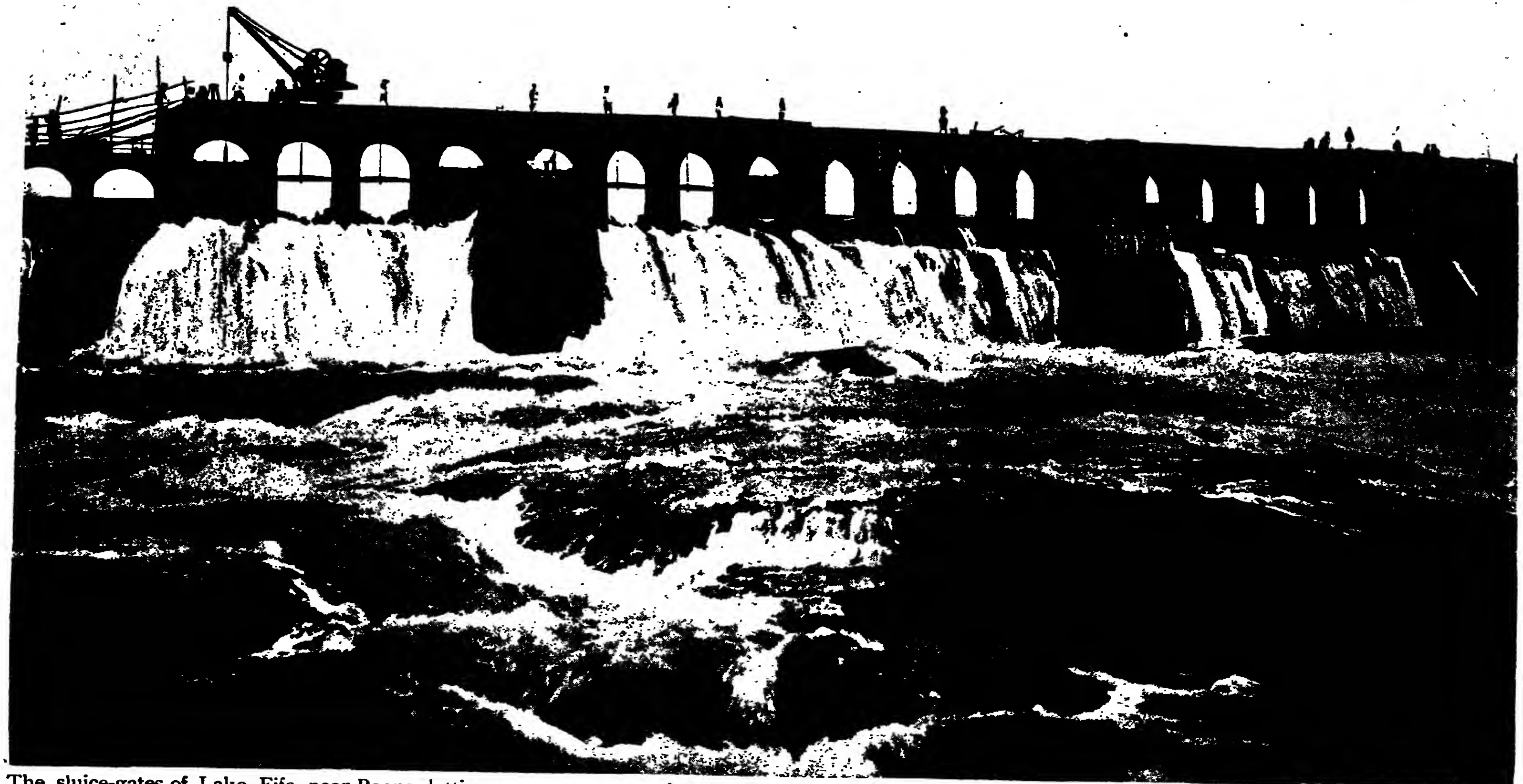
normal level and an escape level, the latter being to give passage to surplus water during heavy floods. One is 31 feet above the other. At the flood level the lake has an area of 7454 acres, the greatest depth being 162 feet. At the normal level it has an area of 3765 acres, and 131 feet depth of water. At escape level the cubical contents are 13,299 millions of cubic feet, and the volume of water available for irrigation is 6815 million cubic feet, sufficient for more than six weeks' supply, without calculating on the storage of any additional water. The water thus stored is carried a distance of 86 miles through a river-bed to the Madura district, where 180,000 acres are irrigated. The total cost was about £500,000.

A vast irrigation scheme is now in progress in the Punjaub, about forty miles south of Lahore, employing 8000 natives of mixed nationalities, superintended by four Europeans only. When completed, perhaps during the present year, it will irrigate annually about 2,000,000 acres, and attract a large population to what is at present an uncultivated waste. The scheme, when completed, will convey the surplus water from the River Jhelum to the Chenab, to irrigate a large area, and thus permit the waters of the Chenab to be drawn off higher up, to irrigate other districts. The whole scheme involves the construction of three canals, the upper Jhelum Canal, the upper Chenab Canal, and the lower Bari Doab Canal. This last canal will be 200 feet wide and 10 feet deep, conveying a volume of water ten times as great as that of the Thames at Windsor. Yet this immense canal has to be carried across the Ravi River, which in flood time has a width varying between one and three miles, and a volume equal to half that of the Nile at Assouan. Another part of the scheme is a barrage across the River Ravi. This will be 1650 feet long, having thirty-five gates, each weighing 18 tons, and measuring 40 feet in length by 12½ feet high.

WELL-SINKING PREPARATORY TO THE CONSTRUCTION OF THE JHELUM WEIR

Before the head-works were commenced, 20,000,000 cubic feet of earthwork had to be excavated and removed. About 30,000,000 bricks are being used, and 1,000,000 cubic feet of lime. About 500 train-loads of stone had to be brought by rail 185 miles. When the head-work is

THE UNTIMELY ESCAPE OF A THIRSTY NATION'S TOO PLENTIFUL WATERS



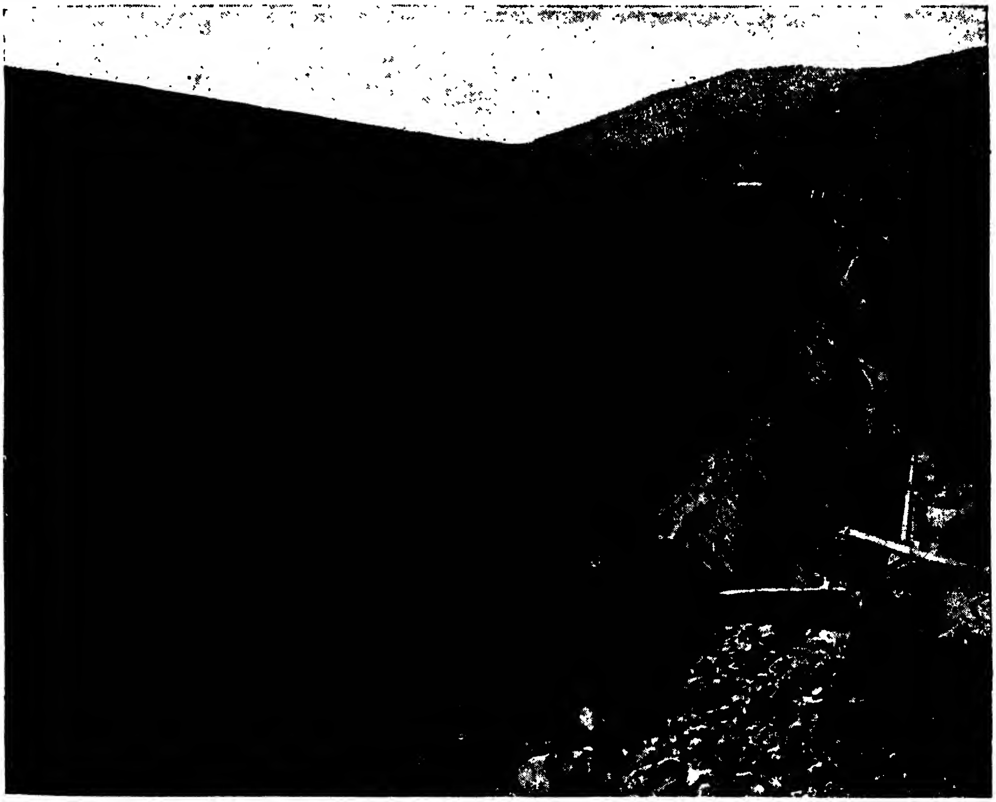
The sluice-gates of Lake Fife, near Poona, letting storm-water pass into the waste weir. Eighty-five gates, along a crest of four hundred yards, let as much as seventy-five thousand cubic feet of water go by every second.

completed the River Ravi will be diverted into a new course to the weir at the level crossing.

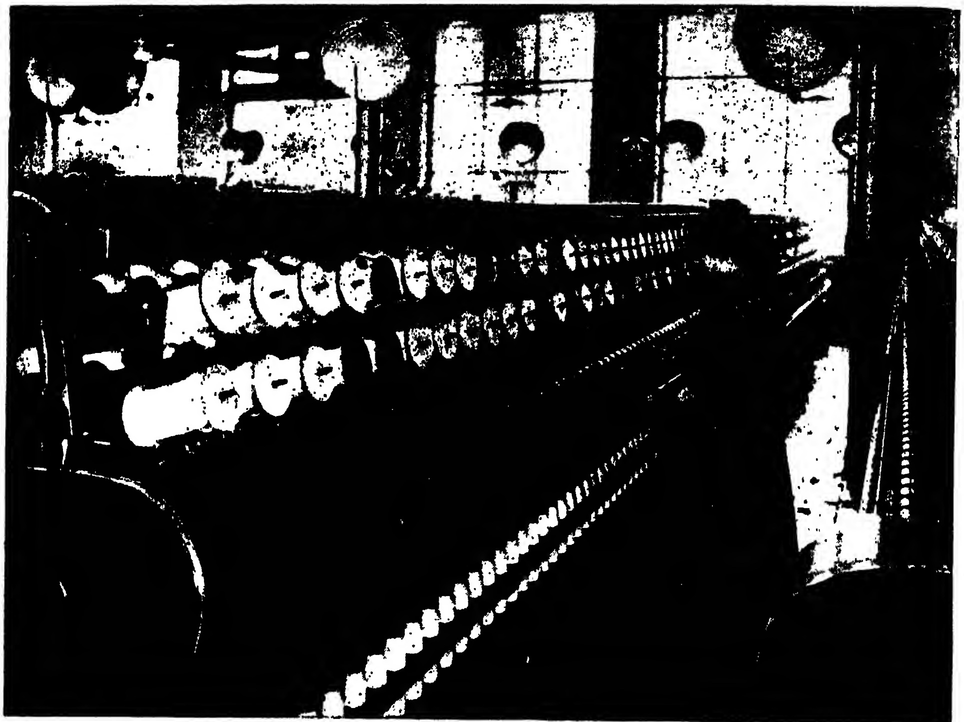
Another immense work now in progress lies in the Upper Swat valley, on the North-West Frontier of India. This is supplementary to work begun more than thirty years ago in the lower part of the valley. On the northern side the valley is cut off from the Swat River by high hills that are now being pierced by a tunnel through the Malakand Pass. It will be 11,226 feet long, 18 feet wide, by 12 feet high, bored mostly through very tough granite. The head-works are at Amandara, 3½ miles below the Chakdara Fort. Thence the canal, 100 feet wide and 6¾ feet deep, will run through four miles of the Chakdara Valley to the head of a tunnel, that will slope 1 in 215. At the southern end the water will fall into the Dargai nullah, which has a fall of 322 feet in a length of five miles. Beyond that it leaves the hills. The water of the Swat River drives turbines and electrical machinery for drilling the tunnel. Four hundred drills have to be ground daily, so hard is the rock. Half a dozen machines are at work at each end of the tunnel. Gelignite is the explosive used.

In the last official return made (1911), there are 1326 miles of main State canals in course of construction, and 4939 miles of distributing canals, by far the greater proportion being in the Jhelum, Chenab, and Bari Doab Canal schemes in the Punjaub.

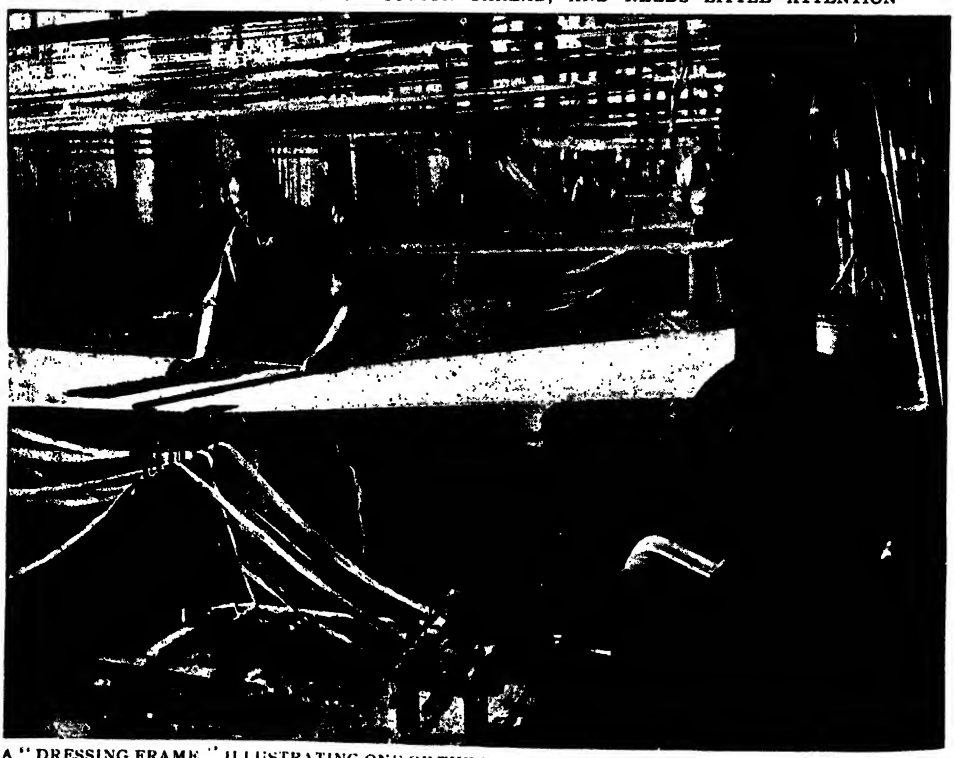
The work of irrigation in India is not yet completed. Of the total rainfall in India only a very small proportion is utilised in this way. Over certain areas watered by the principal rivers in India, covering 1,434,000 square miles, excluding Burma, Assam, and East Bengal, and on which the average annual rainfall is 37½ inches, 125 billion cubic feet of rain-water fall. Of this a volume of 51 billion cubic feet results in surface flow, from which only 6¾ billion cubic feet is held back or diverted for purposes of irrigation. And of this not more than 50 per cent. is delivered on the fields. Irrigation, therefore, has much scope.



THE MASSIVE DAM OF THE PERIYAR RESERVOIR



A MACHINE THAT "DOUBLES" COTTON THREAD, AND NEEDS LITTLE ATTENTION



A "DRESSING FRAME," ILLUSTRATING ONE OF THE FINISHING PROCESSES IN COTTON MANUFACTURE

The photographs on these pages are by courtesy of Messrs. Horrockses, Crewdson, and Company

OUR WEALTH FROM COTTON

An Industry which Furnishes One-Fourth of the Aggregate Exports of British Goods

GROWING, MANUFACTURING, GAMBLING

It is a proud position which the British cotton industry holds in the vast bulk of British commerce. As we saw in Chapter 7, the work of all the people of the United Kingdom produces in a year, as the net result of all their manufacturing, importing, and exporting, a bulk of material goods worth about one thousand millions sterling at wholesale prices. So largely does the cotton trade contribute to this total that its yearly output is worth about £140 millions, which is about one-seventh of the whole. Even more remarkable is the predominance of the cotton industry in our export trade, in which it bulks for about 25 per cent. of the whole; indeed, in 1911 more than one-fourth of the total exports of British goods was composed of cotton yarns and manufactures.

The International Federation of Master Cotton Spinners' and Manufacturers' Associations makes a continuous survey of the world's cotton trade, and its reliable records are eloquent of the extraordinary and almost incredible superiority of Lancashire's staple, not only in the United Kingdom but in the world. The United Kingdom, the United States, and Germany together own most of the world's cotton spindles, and of these three leaders the United Kingdom is easily first. Here is the latest summary made by the Association:

THE WORLD'S COTTON SPINDLES
AT THE END OF AUGUST, 1911

Country	Number
United Kingdom	54,500,000
United States	28,900,000
Germany	10,500,000
Russia	8,700,000
France	7,300,000
India	5,200,000
Austria	4,600,000
Italy	4,600,000
Total—above and other countries	137,300,000

It is remarkable that the three nations at the head of the table own three-fourths of the whole world's cotton spindles; it is even more remarkable that the United Kingdom owns about 40 per cent. of the whole. Even this proportion does not properly express Lancashire's lead, for a spindle may be spinning coarse yarn of little value or fine yarn of high value. The British spindles include a very large proportion which produce fine yarns, or "fine counts" as they are called; and if this be taken into account, it is probable that the United Kingdom produces nearly one-half of the value of cotton goods of the world measured by value.

It is not surprising that the United States occupies the second position. She is the chief producer of the raw material itself. She has a population twice as great as that of the United Kingdom, and she has a large Southern population which for climatic reasons makes a big call for cotton clothing. On the other hand, the United Kingdom can only employ cotton for underclothing and for admixture with wool in various fabrics. The gigantic proportions of the British cotton trade depend upon foreign and Colonial markets, chiefly the former. We take an exotic product which Nature forbids us to produce ourselves, work upon it, increase its value enormously, and export the results to every part of the world. No trade better exhibits the mutual reactions of industry and commerce. The value of the raw cotton imported for use in British mills and factories in 1907, the year of the Census of Production, was £61 millions; the total value of the cotton goods produced in 1907 was about £140 millions, of which £110 millions' worth was exported. How clearly we see the dependence of British industry and British wealth upon materials brought from over-sea!

During the last twenty years of the nineteenth century, our cotton exports remained almost stationary, at about £70 millions, sometimes rising above and sometimes falling below this figure. In the twentieth century, however, there has been a rapid rise, to £120 millions in 1911. This figure is enormously greater than the exports of all the rest of the world put together, the combined exports of cotton goods by the United States and Germany being about £30 millions, and the other countries counting for comparatively little, as will be gathered by the spindle record.

The maintenance of British exports being such an imperative necessity, what prospect is there for the British cotton trade? When one examines the spindle record, one is tempted to think it probable that it may be difficult for the United Kingdom to maintain such an overwhelming advantage. That is probably a correct impression as far as *relative* superiority goes. It is not reasonable to suppose that Lancashire can for all time continue to possess 40 per cent. or so of the world's cotton machinery. On the other hand, there is not the slightest reason why Lancashire's *actual* trade should not increase, even though her relative position may suffer. The uses of cotton are universal; and what between the rapid increase of the world's population, and the rapid rise in the general standard of living all over the world, the cotton goods market is susceptible of indefinite expansion in the near future.

There are upwards of 1600 million people in the world, and before very long there will be 2000 million. If we imagine a consumption of cotton goods throughout the world of as little as ten shillings per head, we have a total trade worth £1,000,000,000 per annum, and this may be easily doubled, or even quadrupled. In the time to come, Lancashire may easily come to possess a trade enormously greater than that she is proud of to-day, although her proportion of the whole may fall considerably. These considerations are of the deepest importance, and they show how unnecessary it is to imagine that foreign growth is inimical to British interests. Forty-five millions of people and their heirs cannot expect to do the bulk of the trade of a world of 2,000,000,000 people and their heirs; they can by enterprise and with the aid of science not only maintain but largely increase their actual trade.

The chief difficulty with which the cotton trade of the world has to contend is the fact that the world's cotton is so largely produced in one country, the United States. If we look at the International Association's record of cotton consumption for the cotton year ended August 31, 1911, we find that the industry is for practical purposes dependent upon the American crop.

THE WORLD'S CONSUMPTION OF COTTON
FOR TWELVE MONTHS ENDED AUGUST 31, 1911

Source of Cotton	Bales of 500lb.
United States	11,600,000
India	3,600,000
Egypt	700,000
Other countries ..	1,900,000
Total	17,800,000

It will be seen that while India has a considerable production, she can hardly be said to rank with the United States as a producer; for practical purposes the cotton world is at the mercy of the United States. It is a most unfortunate position for all the countries which possess cotton mills, but, above all, it is unfortunate for Britain, by virtue of her overwhelming predominance in the trade.

It is not a light matter that the welfare and means of livelihood of millions should be dependent upon a single source of supply. The United States, either by her own ill-fortune or by the abuse of commerce by her speculators, may at any time bring the cotton operatives of almost the entire world to the point of starvation. Crops may fail and produce natural scarcity, or "bulls" on the Cotton Exchanges may raise prices artificially, or there may be an evil combination of natural and artificial dearness. With half a dozen or a dozen great suppliers, such contingencies might be faced in the confidence that many parts of the world are not likely to fail simultaneously; with three-fourths or thereabouts of a supply of raw material coming from a single country, the cotton trade is peculiarly the sport of natural and artificial scarcity. It is true that the cotton crop of the Southern States of America has greatly increased of late years. Indeed, it is roundly twice as great as it was twenty-five years ago. It does not increase, however, as rapidly as the world-demand; and what we have said as to the possibility of demand will show that it is not well to rely upon possible further increase in the American crop.

Both the crop itself and the conditions of its production in the Southern States are inherently variable. The cotton crop has a thousand enemies. Every part of the plant is the prey of organic disease or insect

life. The cotton boll weevil alone has cost the Southern planters scores of millions of dollars, and, by injuring the planters, has indirectly injured workers in far-off lands.

The weevil is just a little beetle which punctures the cotton boll—as the unripe cotton pod is called—and inserts an egg. The egg duly hatches out, and the young maggot finds itself surrounded, through the thoughtfulness of its parent, with a store of living food. In ten to twenty days it increases its weight some thousand-fold, and changes into a chrysalis, or pupa, within the ruined boll. In about ten days more the beetle emerges from the pupa, bores a hole through the outer covering of the cotton boll, and escapes, to become the parent of many more cotton destroyers. In a single season there are many generations, and in a cotton-field at any one time the insects may be found as eggs, as grubs, as pupæ, and as beetles. This destructive insect invaded the Southern States about fifteen years ago, and it has been found very difficult to eradicate it.

The Handicap in Cotton Growing by Insect Pests, Uncertain Weather, and Sloth

Then there is the cotton worm, which is the caterpillar of a small moth. This is more easily dealt with, but its ravages are great. Altogether, nearly five hundred varieties of insects are known to infest cotton, and they play a large part in the economics of the cotton industry.

And, apart from such pests, there are the ordinary variations which attach to all farming. The cotton planter never knows when unsuitable weather may come to ruin his hopes. One day he may be rejoicing over his crop, and the next mourning the certainty of failure.

To these considerations we have to add the peculiar characteristics of the negro tenant-planters and labourers of the South. Planters are of many grades, from whites, who produce on a large scale, down to thriftless negro tenant-farmers, who farm small patches of land and the means of working it, and pay rent in the form of produce. In some districts the great majority of tenant-farmers are negroes, who are furnished by the planter with twenty acres or so of land, a house, mules, implements, forage, and seed, and who pay over half the crop as rent and interest. Not more than about one-third of the cotton crop is raised by whites; and as the negro has no illusions as to the dignity of labour, and has not the slightest desire to earn a penny more than suffices to buy him simple fare, it will be understood that, although the possibilities of an enlargement of the American cotton crop are exceedingly great, it is difficult in practice to secure due expansion. It follows that the need for stimulating the growth of cotton in other parts of the world is urgent.

The World's Need of a Wider Field of Supply for Material

If fresh supplies are not secured, there will be a most disastrous check to Lancashire's progress—a check which will be felt by many people in the United Kingdom beside those directly engaged in the cotton industry, for, as we shall do well always to remember, each trade is in some measure linked up with all trades. It is a very great pity that those responsible for the governance of the British Empire did not realise the true state of the case many years ago. There can be no question that, if there had been proper forethought and experiment, the cotton trade to-day would be free from what has become a constant source of difficulty and loss.

There is no reason at all why the industry should be dependent upon America. Columbus found cotton growing wild in the West Indies, and there is no evidence to show that cotton is indigenous in the Southern States. Indeed, the famous Sea Island cotton owes its name to the Bahamas, from which its seed was originally introduced into Georgia.

In spite of this, most of the Southern planters believe that cotton growing on a large scale is impossible outside their favoured country, which, they think, was specially designed by Providence for cotton purposes.

The Strange Belief that One Nation Holds the Cotton Supply by Divine Endowment

Thus, a Governor of Louisiana, at a New Orleans banquet a year or two ago, declared that the South could produce, and would produce, one hundred million bales of cotton, and closed an eloquent speech with the expression of hope to the European cotton spinners present that, after visiting his glorious country, they would "give up the idea of raising cotton in Africa, a country where God never intended that cotton should be grown." In similar vein, the editor of the Boston "Textile World Record" has stated that "no fear whatever is really felt of the competition of the European Powers in the growing of cotton."

The British cotton spinners, wisely taking a wider view of the intentions of Providence,

have formed the British Cotton Growing Association, to promote cotton growing in suitable regions under the British flag.

In India, the Association has stimulated the State Agricultural Department to take up the question, and, by the establishment of experimental farms and the instruction of native planters, it has secured a substantial increase in what is certainly a most favourable region. Already a large addition to the Indian crop has been made by these efforts. In Sind, conditions are not dissimilar from those of Egypt, where long-stapled cotton is grown with so much success, and good results have been secured.

In 1911, Sir Charles Macara reported to the Eighth International Congress of Cotton Manufacturers, at Barcelona, that it had become clear that the possibilities of Indian cultivation were very great, and that "it is to India that the present generation will have to look for relief from shortage of raw material." The association has also encouraged planting in the West Indies where cotton is indigenous. In British Central Africa and British East Africa, Rhodesia, South Africa, the Soudan, West Africa, Sierra Leone, the Gold Coast, and Nigeria large-scale experiments are proceeding, and promising crops in some cases brought to market. One of the directors of the British Cotton Growing Association has expressed the opinion that Nigeria alone will, in twenty years' time, be able to supply ten million bales of cotton a year. Australia has also been mentioned as a possible source of supply, but the high cost of labour appears to stand in the way of producing crops which can compete with material from lands where native labour is used.

And not alone the British cotton manufacturers are taking action. France is experimenting in a number of her African colonies, and Germany has hopes of success in Togo and German East Africa. Some of the German cotton spinners are themselves embarking capital in East African cotton plantations.

THE LOVELY PROGRESSION OF THE COTTON PLANT AS IT UNFOLDS ITS RICHES

The ripening of the cotton plant may be traced through the sequence of numbers above. 1 is the blossom; 2, the flower; 3 the flower, second day; 4, the flower at night; 5, the burr; 6, the young boll; 7, the boll bursting; 8, the boll nearly ripe; 9, the boll ripe; 10, the cotton blown by the wind

In the meantime, the cotton industry of the world is ever demanding a larger supply of material, and it can easily absorb an additional half-million bales every year. Moreover, as we have seen, the rise in the standard of life throughout the world has become so rapid that demand is racing ahead of supply and accelerating in pace.

Under these circumstances, we need not be surprised if the Southern planters are beginning to feel their power. We have seen how uncertain are their gains under ordinary conditions, and in the past they have often suffered bitterly through the work of the intermediaries to whom they sell their products. In the old days, when the electric cable was undreamed of, the British cotton user bought American cotton through an agent in America. With the growth of the cotton trade, cotton merchants naturally arose in America who bought from the planters judiciously, and took the material to market, taking the normal risks of a merchant trade, and working under the conditions of ordinary speculation which inherently attach to such a form of business. Then, as the trade still grew, came the Cotton Exchange.

More than forty years ago these Exchanges began to be established, at New Orleans; North at New York, and across the Atlantic at Liverpool. And then, in the wake of the Exchange, came the possibility, not of the ordinary commercial speculation which attaches to the real buying of a real product with the hope of selling it at a profit, but the gambling of the Exchange in "options" and "futures."

What Speculation in Futures and Options Really Means

A contract is entered into to sell cotton at a certain price for a certain future date, just as, on the Stock Exchange, a broker agrees to sell or to buy at a certain price and to deliver or to take up, as the case may be, at that certain price on a certain settling-day. When a cotton broker sells cottons for delivery at a future date, and sells at a price agreed upon when he makes the sale, he sells a "future."

An "option" is a power to buy or sell cotton before a certain date at a price fixed in the present; the power to sell is a "put," the power to buy is a "call." The term "option" expresses the fact that the "put" or "call" is exercisable at the option of the man who acquires it.

How different this machinery of exchange from the straightforward, real buying of real cotton by a merchant who hopes to profit by its sale! There is all the difference in the world between the speculation involved in real buying and selling, and the sheer gambling played with counters which often represent what those who deal in them do not possess and do not require. The man who buys a "future" is not necessarily buying cotton, but as often as not the mere hope of making a "turn" through a rise of price before settling-day which enables him to sell out at a profit before delivery is due. He, of course, is the "bull." The man who sells a "future" has often no cotton to sell, but hopes for a fall before the future settling-day, to enable him to buy in at a lower price, and clear a turn. He, of course, is a "bear." Very often parties in these contracts have never seen a bale of cotton in their lives, and have not the faintest idea how it is grown or how it is manufactured.

The Incalculable Harm Done to the Trade of the World by Cotton Gambling

It is not that a contract for future delivery is not a legitimate and helpful thing; it is that it is terribly unfortunate for honest producers and consumers that it opens the door to the illegitimate speculation which harries industry, and often works havoc in the employment of hard-working people.

It is when cotton is naturally scarce that the speculator is able to work to his own greatest advantage, and to the greatest mischief for the world at large. A clever or lucky speculator who correctly anticipates a shortage, and who corners a commodity, may be able to catch the bears "short," and run up prices to an extraordinary level. In doing so he may make a fortune, and throw out of work industrial operatives by the thousand. Such things have occurred, unfortunately, in the cotton trade; and we may recall that a few years ago an American who had cornered cotton was hissed on the Liverpool Exchange, and found it advisable to hasten his departure from the seat of the British cotton industry.

Gambling in futures is accompanied by every kind of chicanery. It resorts to deception, to misrepresentation of crop reports, to wantoning with honest cotton as though it were not one of the most intrinsically valuable of materials, but as though the hardly won bales were so many pawns in a game.

The Attempts of American Growers to Counteract Speculation

It is impossible to believe that such methods will survive the twentieth century, or even the first half of it. We need not be surprised if those who produce cotton, and who are subject, as we have seen, to many trials and vicissitudes, have recently come to the conclusion that if there is to be artificial dealing in the commodity they produce, they ought to have a hand in it.

Within the last ten years great Planters' Associations have sprung up in the Southern

States in order to secure a voice in the settlement of the price of cotton by the planters. An interesting account of these was given to the Fifth International Cotton Congress of 1908, by Mr. Moritz Schanz, of Chemnitz, who is a member of the German Colonial Cotton Growing Committee which is endeavouring to cheapen cotton by promoting Colonial plantations. Mr. Schanz points out that the planters are perfectly justified in moving against the evils of speculation and in endeavouring to steady prices.

The Need for Association Among the Genuine Users of Cotton Products

The primary cause of the planters' combination movement was the violent fluctuations of price brought about by speculation. Within the short space of eight months there has been known a variation of as much as sixpence a pound in the price of cotton. That means a difference of £12 10s. in the value of a bale of cotton. In consequence of mad speculation in New York, there was a fall in the price of cotton from eightpence-halfpenny a pound in May, 1904, to threepence-halfpenny a pound in January, 1905, causing heavy losses, as may be imagined, to the planters. Examples of this kind might be multiplied; and no one can blame the planters for replying to the speculators of the North with combination in the South. The Farmers' Educational and Co-operative Union was established in 1902, and has its headquarters at Dallas, in Texas. The Southern Cotton Association was formed in January, 1905, being a development of an older Cotton Growers' Protection Association; its centre is at Atlanta, in Georgia. These two associations have between them nearly four million members, and they are beginning to play a big part in the cotton world. If they are tempted to reply to the cotton speculators in the spirit of cotton speculation, we can hardly blame them, for they did not begin the game, and they have far more right to play it than those who merely trifle with contracts which represent the work of others.

The Power Over the Trade of the World that Might be Commanded by the Growers

There was a time when the cotton planter found it necessary to bring his cotton to market quickly in order to realise cash; indeed, he often mortgaged his crop before it was grown. As for the poor negro cotton tenants, it is still held by some that the only way to make them work is to keep them in debt. So far as the white planters are concerned, they have largely recovered during recent years from the depressed conditions which followed the Civil War. By the aid of their associations, they see their way to hold up their product instead of seeing it held up by speculators. The Southern Cotton Association controls a large proportion of the entire production of the Southern States, and is able to finance a considerable proportion of it. It is obvious that in view of the large proportion of the world's crops which is grown in America, a high degree of combination would enable the planters to tax the entire cotton industry of all nations.

The growers' combines aim at a system of storage throughout the cotton area, with sale-offices in connection therewith. An advance is made to the planters on cotton stored with the associations. A large part of the plan has been carried out. Memphis has warehouses in which hundreds of thousands of bales can be stored. Texas has hundreds of cotton warehouses established by the Farmers' Union, with a bale capacity in seven figures.

The Necessity for Complete Elimination of the Speculative Broker by the Handlers of Cotton

With the consciousness of power acquired, the planters talk of fixing minimum prices for cotton, fifteen cents, or sevenpence-halfpenny, a pound being mentioned as a figure necessary to the planters "in the interests of the education of their children and of a dignified human existence." The association denounce all middlemen, especially their own countrymen, and they state that they will eliminate speculation. Dealing in "futures," not only in cotton, but in all agricultural products, is to be fought; and we may take note of the fact that since 1906 the planters' combinations have secured legislation against "options" and "futures" in a number of the cotton States—viz., in the Carolinas, Georgia, Alabama, Arkansas, and Texas. Their aim is to clear all middlemen out of their path, and to deal directly with the cotton spinners, securing from the latter a minimum price.

It must be confessed that there seems nothing chimerical in the planters' aim. In these days of the growth of large dealing, it should not be more difficult to co-ordinate and control the cotton output of the Southern States than to co-ordinate and control the many branches of that enormous combine the United States Steel Corporation. If we imagine the Southern planters sending their product to central warehouses controlled by a co-operative selling trust, which would gin the cotton and grade it,

surely such a trust would have no difficulty in establishing relations with cotton buyers all over the world, and in completely eliminating the entire army of American speculative middlemen. If such a consummation is achieved, the speculative brokers will have only themselves to thank.

On the other hand, such a Southern cotton trust would be a monopoly wielding powers which might make it more formidable to the world's cotton buyers than the existing system. It is obviously necessary, therefore, for the cotton masters of Europe not to rest until they have secured ample supplies of cotton by stimulating cotton growing in India, in Asia, in Africa, and, indeed, wherever latitude and climate favour it. They may be greatly aided in this by the newly found control of tropical diseases. They must also receive the liberal aid of Government. The British Government, especially, can do much, for no other Power has rule in so many favourable regions. Time was when Government enterprise of the kind was unhappily frowned upon; and curiously we associate with Manchester herself the doctrine of "let-be" which for so long was the sole guide of the British statesman. To-day we see Lancashire herself urging the Imperial Government to make grants in aid of cotton growing, and to build African railways to assist it. That is a change which is typical of much; and it shows how we have fortunately won out of the days when it was thought good to leave the development of the nation and of the Empire to the sole direction of the chance play of forces exercised by private profit-makers.

Let us take a broad view of this difficult matter. It is one in which the producers and consumers are seen to be at cross-purposes, and it well illustrates the fact that in some directions commerce is not yet as fully equipped or as well developed as industry.

What perfection the cotton industry has achieved has already been shown in Part 3 of this publication. To examine the work, first, of the cotton spinner who produces the yarn or the thread, and next of the cotton manufacturer who buys yarn from the spinner and weaves it into all sorts of coarse and fine cloths, is to witness wonderful operations which win simplicity out of an apparent complexity. Science has so perfected the machinery that an enormous amount of cloth can be produced with very little labour. We have seen that the British cotton industry had in 1907 an aggregate output worth about £140 millions. The Census of Production Report of that year showed that the average number of persons employed in the year was 572,869—viz., 560,478 wage-earners and 12,391 salaried persons, the total number being distributed according to age and sex as follows.

EMPLOYMENT IN THE UNITED KINGDOM COTTON INDUSTRY IN 1907.

Males	
Under 18 years of age ..	.. 51,709
Over 18 years of age ..	.. 168,854
	220,563
Females.	
Under 18 years of age ..	.. 90,061
Over 18 years of age ..	.. 262,245
	352,306
Total—Males and Females	.. 572,869

It is not a little remarkable that so few people should have such a large output. If we count as an adult a person over eighteen, we see that only about 431,099 men and women are employed in the cotton industry, aided by 141,770 boys and girls, some of whom are half-timers. *A century ago millions of persons would have been needed to produce what these 572,869 people produce.* Science has made it possible for one man to do the work that ten, twenty, or even fifty men could do in, say, 1800. If the reader will turn to Part 3, page 347, he will see illustrated a spinning-mule which, tended by one man and two boys, can spin as much cotton as four thousand women could spin in bygone days.

Unfortunately, it cannot be said that commerce has made a corresponding advance. There is not a similar perfection in the arrangements which take cotton from the cotton-fields and place it at the disposal of England, or Germany, or France, or Italy. We have seen, on the contrary, that cotton planters and cotton spinners are equally dissatisfied by the imperfections of existing arrangements.

A moment's consideration will show that the real interests of a cotton planter and cotton user are one and the same. The cotton planter grows cotton for the use of the spinner. To him, therefore, the spinner is really the desirable person who wishes to receive the very commodity which the planter works to give. On the other hand, the cotton spinner is helpless without cotton to work upon. and to him

the cotton planter, whether in the Southern States, or in Egypt, or India, or Brazil, is the indispensable complement of the cotton mill. Cotton planter and cotton spinner are in essence as mortise to tenon, or as lock to key. If, then, we find them, as we do, at cross-purposes, we have clear evidence that commerce is not yet filling to perfection its essential and proper function of distributing the products of industry, and of bringing together in harmony and concord the man who produces and the man who consumes.

The Disharmony in the Cotton Trade Between the Producers and Distributors

To understand how great is the disharmony which prevails in the cotton trade, considered as a whole, let us turn to the records of the various international congresses of delegated representatives of the world's Master Cotton Spinners' and Manufacturers' Associations. We find again and again the discussion of the need for international agreement between the world's cotton producers to restrict output by organising general "short time" *in order either to keep up the price of cotton goods, or to reduce the price of the raw material from which they are made.*

Let us think what this means. If cotton mills work short time, it is exactly the same thing as though suddenly all the machinery in the cotton mills became less effective. Suppose the international agreement is to reduce output by 10 per cent. The same result would be secured by the machinery becoming to that extent ineffective. That being so, we have demonstration that commerce is so much less effective than industry that distribution is as yet imperfectly brought about, that machinery is too good and too rapid for the methods of commerce. To put it in another way, cotton spinners can make yarn and cotton manufacturers can weave cloth more rapidly than commerce can distribute the products.

The Failure of Commerce to Distribute the Goods which the Manufacturer Produces

To such a pass does this come that at the Sixth International Congress, held at Milan in May, 1909, we find an English cotton master saying: "English spinners do not hold so tenaciously to full time as some of the delegates may imagine. During the last twelve months they have worked short time to the extent of five full weeks, in addition to a seven weeks' stoppage through the lock-out. We are all aware that it is difficult to get Continental spinners into line on short time. I am convinced that the greatest troubles that ever arise in our trade are owing to a want of unanimity. I do not want to see so good a trade as there was in 1906–7. We can do with less; but I do say we are entitled to be remunerated for our work, and the workman should have a living wage. Neither do we want to starve the cotton grower."

This is a most suggestive utterance. We see a cotton master compelled to stop his proper business of turning out as much stuff as possible and as cheaply as possible because over-production quickly follows upon ease of production, and causes loss to the producer. That points to disharmony and severance where there ought to be perfect concord and conjunction. If commerce were as scientific as a modern cotton loom, or type-composing machine, or piece of artillery, it is clear that, the more rapid and plentiful production came to be, the better it would be for every agent concerned.

The Better Augury for the Future in the General Co-Ordination of Trade

Wherever we find a gulf between producer and consumer, whether it be between cotton planter and cotton spinner and cotton manufacturer, or between cotton manufacturer and the citizen who needs cotton goods, we have evidence that commerce is not yet performing its functions with due celerity. The fact that it is easier to make things than to distribute them is an expression of the fact that industry is more advanced than commerce.

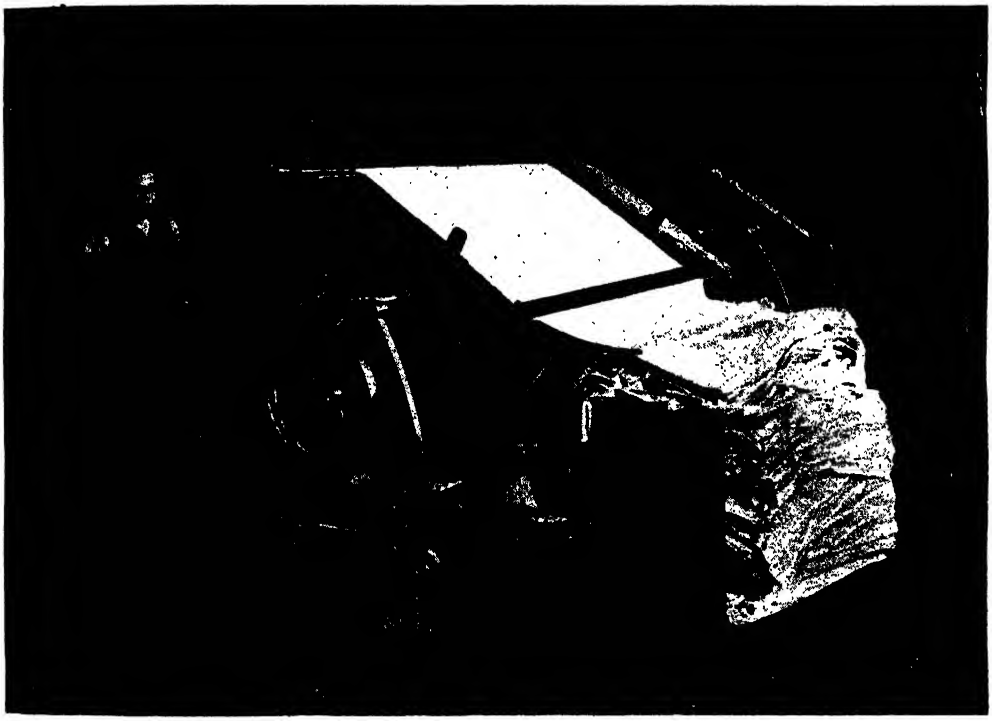
The International Congresses of Cotton Masters, to which we have referred, are full of hope for the future of both industry and commerce. The sixth Congress, to which we have referred, met at Rome, at the beautiful palace which has been erected by the King of Italy for carrying on the work of the International Institute of Agriculture. The association of these two bodies points to what we may be well assured will come to pass within the present century, and before it has very far advanced.

Each of these bodies is an attempt to co-ordinate functions throughout the world. The International Institute of Agriculture reports upon the agricultural produce of the entire world, and upon its methods. It sends out reports in many languages, and supplies the Press of the world with gratuitous information, telling each country what the other is doing. Among other things, it reports upon cotton crops and the progress of cotton growing. The International Federation of Cotton Masters

performs similar functions for the world's cotton trade. Its members meet annually, meeting in each country in turn, for the free discussion of their mutual interests. They discuss the technics of their industry, its commerce, its supplies of material, its credit instruments, its contract notes, and its general development. Each country learns from the other, and all gain.

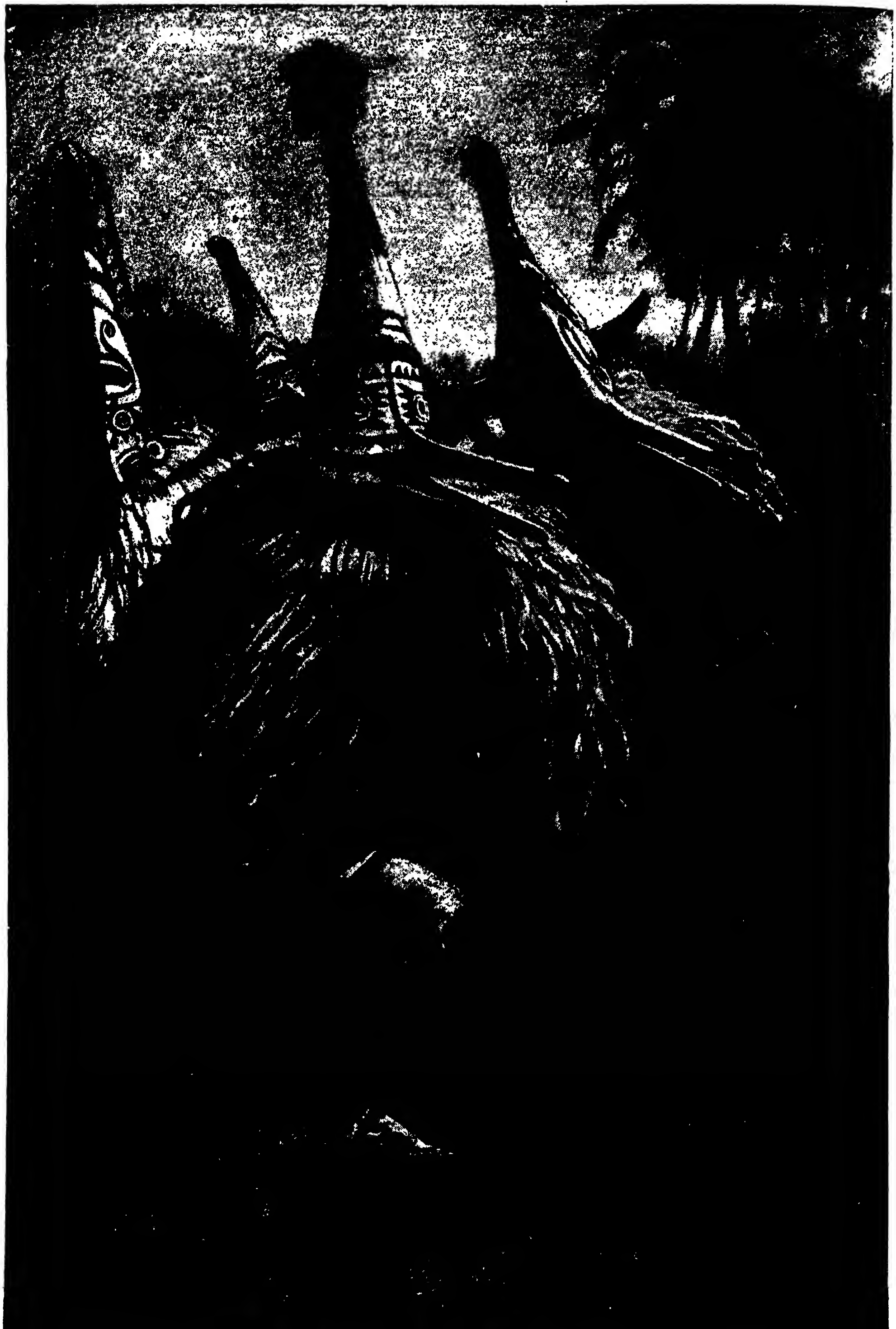
It will be apparent that while the cotton masters who thus meet each other are competitors, their meeting cannot fail first to eliminate what is worst in competition, and finally to eliminate it altogether. We shall see growing up a solid body of international such a combination to work otherwise than for the good of the world. Indeed, it is difficult to see how the world's work is to be carried on to the best advantage without the co-ordination of all the factors of an industry throughout the world, *including the agents who supply the materials.* With cotton planters and cotton users working hand in hand, much economic waste would be avoided, and the entire industry might proceed on its way without wasting energy which ought to be concentrated upon useful economic production.

And, it is important to note, in conclusion, the formation of international industrial



THE FINISHED PRODUCT OF THE COTTON MILLS ON THE FOLDING MACHINE

producers who will cease to cut each other's throats because of its obvious folly, and who will be able to give their minds the more to their proper business of manufacturing. It is true that there are possibilities of undue exploitation of consumers involved. A world cotton trust might conceivably arise, which, by common agreement between its members, could "hold up" cotton productions against consumers, and in effect create a great taxing monopoly. Such a trust, however, would not be tolerated by the world's Governments, and in the long run it would be impossible for associations is amongst the most important factors making for the peace of the world. The leading men of all nations are meeting each other more than ever before in history; and with the growth of friendly communication upon subjects of mutual interest, unworthy suspicions and groundless animosities must disappear, and arrangements that manifestly are for the advantage of all who are seriously engaged in the essential industries of the world must more and more gain universal adhesion, to the exclusion of the preying and unproductive speculator.



MAGIC-MEN OF NEW GUINEA ENFORCING A TABOO THAT ENTAILS HEAVY PENALTIES AND FRIGHTFUL LUCK ON WHOEVER BREAKS IT

THE REIGN OF THE GHOST

How the Fiercest of Primitive Races Came to Respect Human Life and Property

THE ORIGIN OF FUNDAMENTAL LAWS

In any kind of stable government there must be a respect for human life and a respect for property. The central authority, or the community at large, may possess all the property, and may exercise a tyrannical power over the lives of the people; yet the individual member of society must not rob or slay his neighbours. All this is obvious; but the origin of the ideas of ownership and of the sanctity of human life is very far from being obvious. The matter was not plain when Herbert Spencer completed his masterly survey of the evolution of human society, and it is only within the last few years that our younger leaders of science have been able to throw a strange and yet clear light on it.

We have already seen how the art of government was developed by a class of magicians who ruled the people by superstitious fears and practices. Brute force did not play in the early forms of society so important a part as is commonly thought. For we have found in tracing "The Origin of Kingship" that superstition has often been more potent than reason or armed ambition in building tribes into nations.

And what we now aim at showing is that superstition has often done more than laws or material punishments to establish in the mind of primitive and savage man that respect for human life and for private ownership without which the world would have been ruled by successful murderers and thieves. It is patent that the more violent instincts of uncivilised man had first to be repressed, before anything larger than the family clan came into existence. But it is not easy to see at a glance what power there was available to this end. Both primitive and savage man have at times hunted even their fellow-creatures for food; and there was no constraining force outside of their individual selves which could repel them from murder and robbery. Indeed, it must have been the easiest thing in the world to find an opportunity for slaying even a relative out of anger or jealousy or ambition. The ancient hunters were often brave and daring men, who risked their lives almost daily in the pursuit of game. Some of them, even in the Old Stone Age, were the practical masters of the earth, and the huge and ferocious cave-bear was their favourite food. Men such as these had to be forced to respect each other's person in the wildest outbursts of bad temper, while living under conditions of great hardship with practically no social machinery to enforce the respect for human life.

As a matter of fact, the work now done by our highly organised police system, with a judge and a hangman at the end of it, was performed by the murdered man himself. It may have been a dangerously facile thing to kill his body, but that only set his ghost free to haunt the slayer. Primitive man certainly believed in ghosts, and he seems to have had the same superstitions concerning them as the modern savage. Beside the body of his dead he placed a store of food and an armoury of weapons for use in the spirit land. He believed that animals had spirits as well as men, for he has also left, in the caves in which he dwelt, pictures and carvings of the beasts he hunted. They are apparently drawn for magical purposes, and among them is a representation of men disguised as animals going through some magical ceremony.

A great deal of evidence of this sort has lately been discovered among the most ancient of the existing remains of early men. It all goes to show that primitive man had much in common with the modern savage in the matter of beliefs. At one time it used to be argued that no just conclusions with reference to the evolution of human society

could be drawn from the study of existing savage races. It was contended that the modern savage had very likely developed in a direction entirely different from that of the chief primitive tribes of prehistoric times. Well, it is highly probable that some of the customs and beliefs of modern savages are more complicated than those of primitive men, but, on the other hand, there are many indications that the savage has preserved the main lines of very ancient ways of thinking and feeling His mind is almost as much a relic of the Age of Stone as the flint weapons he uses in hunting and warfare. Moreover, we are often able to discover, in the traditions of the most civilised of present nations, vestiges of prehistoric institutions which can only be understood when they are compared with forms of government still obtaining among savages.

The Impressionable and Unsettled State of the Minds of Savages

Now, in regard to the origin of the idea of the sanctity of human life, we must remember that the savage imagination is very impressionable and remarkably childish. Everything that a man of the lower races does not clearly understand frightens him, and makes him uneasy. And as there is very little that he really does understand, his mind is not settled and reasonable. There appear to be good grounds for assuming that he is amazingly susceptible to hypnotic suggestion. Many savages can actually be killed by witchcraft. If they learn that the customary magical rites for destroying them have been performed, they will grow unwell and die—simply through their wildly extravagant and imaginary fears. This psychological fact has more bearing on the origin of certain human laws than have all the theories about social contracts and myths concerning the earliest legislators.

Modern Sentiment about Ghosts a Survival from the Terror of Earlier Times

Greater than the fear of the living magician is the dread of the ghost of a dead person. To the savage way of thinking, the soul of a baby that dies soon after birth may become a very harmful spirit, continually haunting the whole tribe, and bringing disaster upon all its undertakings. The fear of ghosts is hardly extinct among ourselves, and it is practically universal among savage people. All ghosts are dreaded, but the spirits of slain men are especially an object of terror to their slayers and to the community.

In ancient Greece, even an involuntary homicide was exiled for a year, so that the wrath of the wraith of the dead man should have time to cool down. Orestes, the son of Agamemnon, killed his mother because she enticed her husband to a bath on his return from Troy, and there had him slain by her paramour. Orestes' act was an act of justice, but according to the Greek view it did not save him from punishment. The ghost of his mother pursued him wherever he went, and at last maddened him. In this wild and tragic legend is faithfully reflected the ancient Greek conception of the fate which overtakes the murderer at the hands of the ghost.

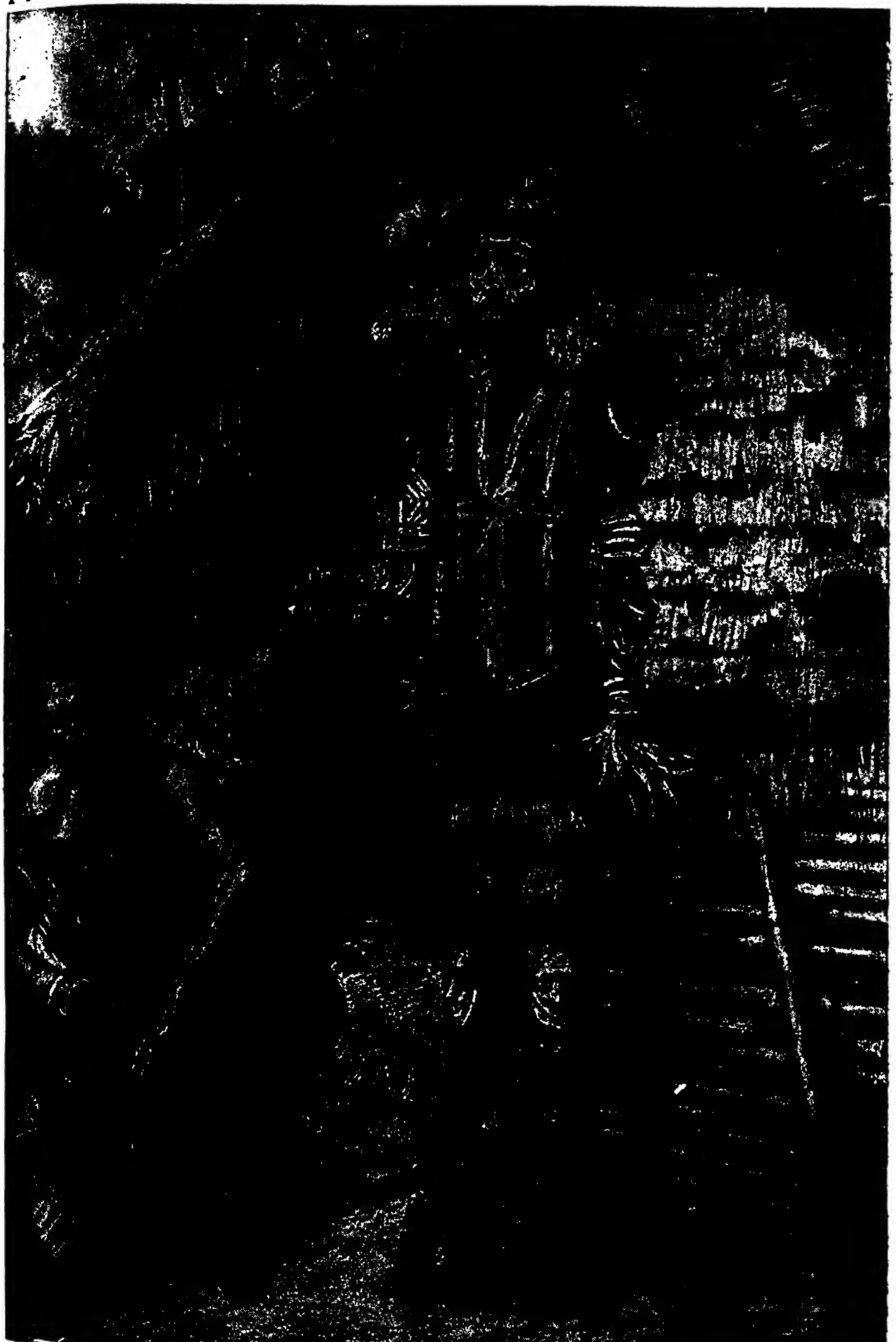
It was more in self-defence than out of consideration for the manslayer that a Greek community compelled him to depart from the country. This is evident from the provisions of the law. In the first place, the homicide had to keep to a certain road when going into banishment. It would have been hazardous to let him stray about the land with an angry and dangerous spirit dogging his steps. In the second place, if another charge was brought against a banished manslayer, he was allowed to return and plead in his defence. He was not, however, allowed to set foot on land. He had to speak from a ship which was not permitted to anchor, and the judges decided the case while sitting or standing on the shore.

The Ghostly Revenges Feared from Murdered Men by Savage People

Obviously, the intention of this rule was literally to insulate the slayer, lest by touching the earth, even indirectly through the anchor or the gangway, he should blight everything by a kind of electric shock. The ghost-ridden man was full of a sort of effluence of death, and any contact with him might kill the crops or spread some plague.

Seeing that the most intelligent and cultivated race of the ancient world, the Athenians, were governed in their respect for human life by superstition, we cannot wonder that many savage and barbarian peoples are still obsessed by similar ideas. Among the Omaha Indians of North America, a murderer whose life was spared by the kinsmen of his victim had to observe certain rules for two to four years. He had to walk barefooted, and never eat warm food, nor speak loudly, nor look around him. He had to tie his robe tightly about him, and keep his hands always close to his body. Even if his hair was free, the ghost might get hold of it. Nobody would eat with him; and when the tribe went hunting, he was compelled to pitch his tent a quarter of a mile from the rest of the people, lest the

THE GUARDIAN STATUE OF A DEAD CHIEF



In the New Hebrides a life-sized statue of a dead chief, painted red and streaked with white, is set up to watch over the welfare of the tribe.

ghost should raise a high wind which might cause damage.

When the spirit of a murdered man is thus feared by everybody, it is natural it should be especially dreaded by those against whom it may be conceived to bear a grudge. For example, when the relations of a murdered man among the Yabim of German New Guinea accept compensation instead of avenging his death, they must get one of their family to mark them with chalk on the forehead. If this is not done, their dead kinsman is sure to punish them for not avenging him. Perhaps they will suffer from toothache, and end by losing all their teeth, or the ghost will frighten and drive away all their pigs!

Laying the Ghosts of Slain Men by Blood-stained Ritual

Practically everybody in a savage community who dies a violent death becomes a public danger. The temper of the ghost is naturally soured, and it is ready to avenge itself on the first person it meets, being too angry to discriminate between the innocent and the guilty. So general offerings of food are made to the spirit by the tribe, in the hope of propitiating it. In some places, however, an attempt is made to frighten the ghost away. Papuan villagers assemble for some nights after a murder has been committed, and beat drums and shriek to drive away the spirit of the dead man. Many Red Indian, Zulu, and Fijian tribes take similar measures to protect the community against the angry ghost. The Bhotias of the Himalayas perform an elaborate ceremony for transferring the spirit of the dead man to an animal, which is beaten by all the villagers and driven away. Having thus expelled the ghost, the people return with songs and dances to their village.

The shedding of blood can often be expiated by some magical rite. This usually consists in sacrificing some animal, presumably to the ghost, and washing the slayer in its blood. The Greek mode of purifying a homicide was to kill a sucking pig, and wash in its blood the hands of the guilty man.

The Penitence and Purification of the Victors in Savage Warfare

The Cameroon negroes smear all the relations of the slayer and the slain with the gore of an animal; and practically all savage races perform some ceremony or act to lay the ghost of slain men. Of course, men killed in battle are just as dangerous spirits as men murdered in the ordinary way. Something has always to be done to evade the terrible results of a victory, or the souls of the defeated host will sweep down and destroy by magic their conquerers. The methods adopted in the defence against the spirits of the slain are too numerous, and often too ghastly, to be fully related here. Acts of penitence lasting for six months are performed by some Red Indians; the Basutos wash themselves in running water with the help of a magician, and sacrifice an ox. Several tribes in various parts of the world shave their heads, a custom which the ancient Greeks at one time followed. Many savage warriors shut themselves up in their huts, and their wives and friends shun them. Others live for a time a hermit's life in the forest, being exiled just as Orestes was, so as to concentrate the malignity of the ghost on themselves, and prevent it from attacking the whole community. Some Australian natives, on returning home from a victory, turn, when their camp is in sight, and perform an excited war-dance. This is really a fight with the spirits of the slain men; and the warriors fancy they can tell by the sound made by their shields whether they have defeated the ghost, or whether the ghost has struck them a mortal wound from which they will soon die. Professor J. G. Frazer has collected a vast store of practices of this kind, which will be found, by readers interested in the subject, in his wonderful work, "The Golden Bough."

How Dread of Ghosts Tends to Preserve Life in Overcrowded China

Nowhere is the fear of ghosts so salutary an influence in enforcing a respect for human life as in the vast commonwealth of China. As is fairly well known, when a Chinaman is suffering under a grievous wrong, he will often commit suicide, and convert himself into an angry ghost, in order to wreak in death that vengeance on his oppressor which he could not exact in life. In another way the general welfare of the Chinese race is promoted by the dread of ghosts. Life is so hard in many parts of the country that married peasants are often strongly tempted to restrict the size of their families by female infanticide. It is the fear that the souls of the murdered little ones will gruesomely punish the parents which prevents the Chinese farming classes from unnaturally restricting that growth of population which may end in China becoming the mightiest of world-powers.

So, finding that superstition has originally done more than any system of laws to keep men from shedding each other's blood, we shall not be surprised to discover

that it has also helped to maintain the respect for private property. As even intelligent animals display a sense of proprietorship, the old theory that individual property was not recognised by primitive men seems to be contrary to facts. When we see the claim to exclusive possession is understood by a dog, so that he fights in defence of his master's clothes left in charge of him, it becomes impossible to suppose that mankind in its very lowest state was devoid of the ideas and emotions that give rise to private ownership.

The Use of Ghostly Fears in the Preservation of Private Property

On the other hand, private property in land is very unusual among savage tribes. The hunting-ground is held in common, and when the hunters develop into farmers the tradition of communal ownership often grows more strong and binding. The tribe depends so much on co-operation in both warfare and agriculture that its territory usually remains a great common possession, binding all the members together. It is to the fruits of individual industry that the sense of private ownership appears first to attach. The problem which the savage has first to solve is to prevent other persons from stealing the weapons and instruments which he has slowly and laboriously fashioned. A Bushman, for instance, sometimes picks up the arrows lost by another hunter in the chase. It would seem natural in the circumstances for him to profit by his find, for he would thereby be saved the trouble of arrow-making. As a rule, however, the Bushman is at pains to return the lost objects to the rightful owner. "How do you know to whom the arrows belong?" a Bushman was asked. He pointed to some marks on the shaft. Marks and designs of a similar kind are found on weapons of the Old Stone Age in Europe, and it is fair to assume they were made for the same purpose.

The Beneficial Action of the Taboo Superstition in Preserving Individual Belongings

This purpose was probably of a magical nature. Every savage regards himself as somewhat of a magician; he may not have those powers of making rain and raising winds and lashing the sea into a tempest which are possessed by the chief wizard of the tribe, but he is confident that he can protect his private belongings. This is done by a magical rite, for which there are various names. In Polynesia it is known as *tapu*; in Melanesia the system is known as *tambu;* in the Malay Archipelago it is commonly termed *pomali;* and in Madagascar it is called *fady*. The rite is widely practised in Africa, and it has been imported by negroes to the West Indies; it also obtains at the present time among native tribes of America, and in many other parts of the world. The South Sea term for it has been naturalised among us as "taboo," but as used by us this word does not convey fully the original meaning.

In the opinion of the natives, the effect of tabooing a thing is to endow it with magical energy which renders it very dangerous to anybody except the rightful owner. Before the natives came into contact with Europeans, the system of taboo worked with amazing success. The most valuable articles might, in ordinary circumstances, be left for any length of time to its protection, in the absence of the owner. If anyone wished to preserve his clothes, his house, his crop, or anything else, he had only to taboo the property, and it was safe. To show that the thing was tabooed, he put a mark to it. Thus, if he wished to use a particular tree in the forest to make a canoe, he tied a wisp of grass to the trunk; if he left his house, with all its valuables, to take care of itself, he secured the door with a piece of flax. The place at once became charged with a sort of curse, ready to fall on any interferer. It meant at least a very bad sickness.

The Importance of Savage Susceptibility to Hypnotic Suggestion

Moreover, the curse could be made retrospective. If a man went to his plantation, and saw that some cocoanuts had been stolen, he ran about shouting imprecations on the thief. As the thief believed in the magical effect of the curse, it naturally troubled him, and worked on his highly impressionable imagination. Men and women have been known to fall dead on learning that, merely by mistake, they had eaten some food which had been tabooed by their chief. This astonishing susceptibility to hypnotic suggestion is a characteristic of many of the lower races, which must always be kept in mind when studying their apparently foolish institutions.

The means by which these institutions are worked seem childish and foolish, because they are connected with a condition of mind away from which many—but not all—members of highly civilised communities have now developed.

The hard, clear reasoning power of the highest races has enabled the best minds

among them to escape from the extravagant power of non-rational suggestion. They have lost, it may be, the responsiveness to suggestion on which mental healers rely, but this loss is more than compensated by a gain in self-control and concentrated reasoning power, which is one of the grand forces of modern civilisation.

To understand the savage and the primitive man, we must attempt to see things from their strange point of view. We must admit that witchcraft can be efficacious when it is used on persons extremely liable to hypnotic suggestion. When we have admitted this, we shall perhaps see that black magic was not altogether a malign and misdirected force in the earliest stages of the evolution of human societies. We are not concerned to maintain that the general good effects procured by the various forms of witchcraft were sufficient to outbalance the numerous and long-enduring bad effects.

Millions on millions of human lives have been destroyed in the course of the ages through superstition. Yet we must not allow our feelings of disgust to blind us to the fact that the strange, unreasonable and impressionable mind of primitive man has sometimes turned to good use the forces of evil that worked in it.

A BAPENDE MAN OF THE CONGO FREE STATE WEARING A GHOST-MASK
From a photograph by Mr. E. Torday

"The New Zealanders," said Mr. A. S. Thomson, in 1859, "could not have been governed without some code of laws similar to the taboo." Warriors submitted to the fear of magic who would have spurned with contempt the orders of men. It was certainly better, having regard to the absence of law and the fierce character of the people, that they should be ruled by superstition rather than by brute force. It was the system of taboo which kept them in an organised state of society. In a masterly work, "The Origin and Development of Moral Ideas," Dr. Edward Westermarck has recently shown that superstitious fears have done much to restrain mankind from theft and murder, from anarchy and immorality. Keeping to our special topic, we can, in conclusion, cite only a few cases out of many given by Dr. Westermarck. In Ceylon, when a person wishes to protect his fruit-trees, he hangs some grotesque figures round the orchard and dedicates it to the evil spirits. No native will then dare to touch the fruit.

Even the owner himself will not venture to use it till the charm has been removed by a priest. Some Red Indians simply surround their plantations with a single cotton thread, and it is believed if any trespasser broke the thread he would die. The negroes of Africa are usually afraid to rob each other, for fear of being killed by fetish magic. In modern Brittany the present writer found that many of the peasants believe that a thief or a perjurer can be made to die of a disease lasting for several months by performing the death vow. In order to see how this was done, we asked one of the rustic wizards to help us to avenge ourselves on an imaginary man for an imaginary wrong. We were conducted at midnight along the bank of the Jaudy, near Tréguier, to a patch of ground on which there had once stood an ancient shrine to St. Yves. The wizard made us kneel down and then knelt down beside us, and recited some prayers in the Breton tongue. Then in bad French he made the vow, asking us to repeat it after him: "Thou art the little saint of truth, and we vow to thee so and so. If he is right condemn us"—the plural is always used—"if we are right, condemn him, and make him die within the appointed time."

Instead of making the vow to St. Yves the Breton peasants sometimes make it to the image of death, carved in the form of a skeleton in some of the old parish churches. Our opinion is that the latter figure, in the early days of Christianity, inherited the cult of the Celtic god of death

worshipped throughout Gaul and Belgium and Britain and Ireland in pagan days. When M. Anatole le Braz, the famous Breton student of folklore, came to London, a year or two ago, we told him of our identification of St. Yves, and the figure of death and the Celtic god of death, with reference to the still living superstition of the death-vow. M. Le Braz said that the same idea had occurred to him. Space does not permit us to give all the evidence we have collected as to the identification, but we may say that we have found various indications of the connection between Celtic deities and modern practices in ancient Irish records, mediæval Welsh literature, and Celtic folklore.

All this goes to support the statement made by Professor J. G. Frazer about twenty-four years ago in an article in which he maintained that "the system of taboo played an important part in the evolution of law and morality." The system was not the creation of a legislator, but the gradual outgrowth of a mass of superstitions, to which the ambition and avarice of chiefs and witch-doctors afterwards gave an artificial extension. In serving the cause of avarice and ambition, however, superstition also subserved the cause of civilisation. It fostered ideas of the rights of property, of the sanctity of human life, and of the marriage tie; and, in the course of time, these ideas grew strong enough to stand by themselves, and to fling away the crutch of superstition which in earlier days had been their sole support.

We shall scarcely err in believing (concludes Professor Frazer) that, even in advanced societies, the moral sentiments, in so far as they are merely sentiments and are not based on an induction from experience, derive much of their force from an original system of taboo. Thus on the taboo were grafted the golden fruits of law and morality, while the parent stem dwindled slowly into the sour crabs and empty husks of popular superstition, on which only the most foolish minds in modern societies are still content to feed. After all, the most baseless superstition of the lowest savage is no worse in character than those silly fancies of certain wealthy women and men which are exploited by fortune-tellers of the present day in the West End of London. The savage, at least, gets out of his superstitions some useful rules of life which go to make him obedient to the best impulses of his childish nature.

A MEDICINE-MAN IN CENTRAL AFRICA

The patient is lying on a mat in the sun, the medicine is in the waterbuck's horn resting on the injured hip, the medicine-man is decorated with white pigment, and by his gymnastic exercises is supposed to be chasing away the disease.

Reproduced by permission from Mr. Alfred J. Swan's book, "Fighting the Slave Hunters in Central Africa," published by Seeley & Co.

The wild, strange fancies of the savage mind have sometimes done more to promote the general welfare of primitive races than any selfishly rational ideas could have done. Clear, precise reasoning power is only an instrument; it can be misused. If a man employs it entirely to selfish ends, he may be more rational in a way than a superstitious savage, but he is less social, less human. He sins against the light. The savage, living in spiritual darkness, manages to obtain some good guidance in life from the most childish notions.

The system of taboo was not, of course, the only force which made for the development of the rights of private ownership. Very interesting is the later process by which land, once held in common by the tribe, became split up among separate owners. A great deal in the current discussion about the nationalisation of the soil is based on exploded theories of the origin of the private ownership of land; so we will next go into this matter from the latest point of view.

THE TERRIBLE PLACES IN WHICH THOUSANDS OF OUR CHILDREN ARE BORN AND BRED

PHOTOGRAPHS OF A TYPICAL MAIN STREET AND ITS ADJOINING COURTS IN THE MEAN PART OF A GREAT BRITISH CITY THAT SWARMS WITH UNHEALTHY LIFE

A SHAMEFUL NEED OF HOMES

The Driving of the Coming Race from the Villages to the Poisonous Slums of the Towns

WANTED—HOUSE-ROOM FOR THE CHILD

We have now traced the demands of Nurtural Eugenics from the true beginning of the individual life up to the possibility of parenthood, and the time of preparation for the ideal of eugenic marriage, by which the race is to be continued. This concludes our care of the individual, from the present point of view, and the whole of the rest of our inquiry must be taken up with Primary or Natural Eugenics, which is concerned with the *inherent* quality of children born. One point of foremost importance, however, remains for inquiry. Parents of any kind, and children of any kind, require a roof over their heads. We have followed the young generation up to the point at which it marries. We must now conclude by studying the environment or nurtural conditions provided to-day for the family in this England of ours. We scarcely can endure to look too closely, but we must look closely enough, before we pass on to study the possibility of reform, and the kind of housing which will be regarded as alone fit for human habitation in years to come.

It is at least clear that there must be available buildings of some kind or other if people are to live. But the Eugenist adds that these dwellings must be available for children if people are to become parents. And there's the rub. For we know that, from the landlord's point of view, children are not to be desired. The landlord may be the squire, or the municipal council, or anything else; in any case, children are looked upon, and frequently described, as encumbrances.

In every part, alike of the country and the town, and not only by individual landlords, but by individuals and corporations alike, marriage is systematically discouraged, and parenthood still more so. There are, of course, a variety of forces which are always tending to discourage marriage and parenthood; but the Eugenist is especially bound to protest that, at present, while we deplore the falling birth-rate, we often decline to provide house-room for children. It is bad enough that the married man, very often, cannot get a situation simply because he is married, but it is outrageous that he should find it so difficult to get a house.

We discuss, as we must, the problems of housing, and they will come prominently into politics in the near future. Meanwhile, we may note that there is not only the problem of replacing unsuitable by suitable dwellings, but also that of providing a sufficiency of any dwellings at all for married men with families. A better supply of these would undoubtedly raise the marriage-rate and the birth-rate forthwith. The present defect in the supply exists both in town and country, but it is especially to be deplored in the country, for reasons which must be briefly stated here.

Exactly as in France or Germany—for the problem is not in the least an insular one—we are faced with the fact of rural depopulation, and every census demonstrates that an increasing proportion of our population lives in towns and cities as against rural districts. So large and general a phenomenon must doubtless be complicated, and we are not called upon to discuss any but its eugenic aspects here. But we are bound to note that urban aggregation increases the risk of various infectious diseases, such as consumption, and that the conditions of city life are unsuitable for childhood in especial. Further, urbanisation is generally associated with a falling birth-rate, and there is a high degree of correlation between urban aggregation and infant mortality. These facts are certain.

It is also probable that city life has subtler effects upon the citizen, which need more search to disclose; and there are observers who consider that the most important of these is the gradual loss of the power of nursing on the part of urban mothers. That this is not necessary is proved by the Jewish mother, for her race has been urbanised for many centuries, and has become more or less completely adapted to its environment. So far as the evidence goes regarding our own race, it appears to suggest that urbanisation is a dangerous process, and that we should do well to retain—or return—a large proportion of our population where the conditions are more healthy and natural.

The Seriousness of the Problem of Housing in the Rural Districts

If these conclusions are valid, they specially bear upon the problem of rural housing, which is to-day receiving less attention than that of the urban housing we are about to consider. It is certain that modern economic conditions do not ultimately require rural depopulation. No factory but earth and sun can grow wheat; and cities must be fed. The peasant must have house-room. In rural England to-day this elementary need is not met. Only too often the young man must either go unmarried or go to the town; if he marries, the country cannot house him. But even such accommodation as exists is open to serious criticism. The sanitary arrangements in most rural dwellings are still very imperfect; and the almost invariably inadequate protection against damp makes chronic rheumatism the cottager's curse. Beyond a doubt attention to these primary matters is required of politicians to-day. They do rightly to begin to attend to the great problems of the slum, and overcrowding, and city planning. But the problem of housing is not solely urban; and the gravity of the urban problem has largely depended upon our neglect of the rural problem.

The Healthy Housing of the Working Classes in the Country a Permanent Necessity

No modification of the city will ever make the country superfluous. On the contrary, the larger our cities, the more necessary is the cultivation of the country to feed them. It follows that the building of none but perfect "garden cities" would still leave us with the problem of housing in the country; and that problem is all the more important if we are right in the belief that our race cannot indefinitely breed with success in cities. Let us look to it, then, amid our other efforts, that we do not neglect the problem of rural housing, which everywhere in this country exhibits numerical inadequacy, and an average quality which is scandalous in an age so late and a land so wealthy as ours.

The results of a systematic inquiry made in 1897 may be cited in conclusion; we know that the facts are worse, instead of better, to-day—fifteen years later. Four hundred villages all over the land were investigated. In not less than half, the verdict on the cottages was either "unsatisfactory" or "very bad." "In over a quarter there were not enough houses for the people to live in." As the most recent student of the subject has said, in the present year: "It is quite unnecessary to quote any more statistics. It is a fact patent to all who travel about the country in England to-day that housing accommodation in the villages is insufficient, and that of what there is much is insanitary."

Five Millions of British People, in Town and Country, Badly Housed

But it is in the towns that some four-fifths of our entire population now live, and it is the towns that furnish the most shameful instances of the housing of the people, for the towns give us the slums, which the worst hovel in the country cannot rival. The magnitude of the question appals those who study it at all. A distinguished authority, Mr. J. C. Nettlefold, in "Practical Housing," says: "It is, I think, understating the case to say that there are at the very least 5,000,000 people in this country living in houses that urgently require improvement either in their fabric or their surroundings."

It is humiliating to compare the facts with the measure of progress made under the Housing Acts. In 1910, the last year for which we have figures, orders were made to demolish 170 houses and to close 1476. There is, of course, no correspondence whatever between these paltry figures and the need. If we look at the great towns of the British Isles the problem is seen in its full magnitude. In London one person out of seven is living under overcrowded conditions; in Leeds, one out of every ten; in Liverpool, one out of every twelve; in Manchester, one out of sixteen; in Edinburgh, one out of three; in Glasgow and Dundee, one out of two. As for Dublin, the capital of poor, consumption-ridden Ireland, 36 per cent. of its total population consists of families living in a single room.

"Those who know what life in a single-room tenement means—living in the one room where the family rears its children, eats, sleeps, dresses, cooks, lives, and certainly dies—will not accuse a well-known social student of exaggeration when he refers to these conditions as 'soul-destroying.'"

The Tendency of Bad Accommodation to Mate with High Rent

London need not boast, when it has Mr. Charles Booth's record to look at: "In one street in Southwark, where there are many single-room tenements, it is said that there are eight hundred people living in thirty-six houses." There is an area in Paddington where 480 persons are living to the acre; and in York, as Mr. Seebohm Rowntree has shown, there are many districts nearly as bad. The writer worked for some time in one of these districts in York, called Hungate, an outrage to God and to man, where children are born into conditions so bad that nothing in the natural history of the animal or vegetable world affords any parallel to them.

Meanwhile, let it be remembered that, in proportion to space occupied, the rent of such places is higher than is paid in Park Lane, and that at least a quarter, and often one-third, of the income of the poor has to be expended on rent. About 9 per cent. of the income of the well-to-do working class family has to be put aside for rent; while as much as 29 per cent. has to go for the rent of the very poor.

In short, the lower we go in the social scale, the higher is the proportion of rent paid, and the dearer is the accommodation. Not merely hygienic but moral considerations soon begin to rise and appal us, until at last we reach the common lodging-house accommodation, and "furnished rooms," with all that these imply for morality, and especially for the destruction of young women.

The High Death Rate Associated with Back-to-Back Houses in the North

But this question of the relation between housing, overcrowding, decency, and immorality cannot be adequately dealt with here. We can only record the opinion of those who know that these facts of the shameful housing of the people largely underlie immorality of the worst possible, often indescribable, kinds. But let us now turn to the effect upon health.

We rightly deplore the dirty condition of school children, and many have argued that the fault is all their mothers'. But there are parts of Manchester, for instance, where one water supply is shared between twenty, thirty, and even forty houses. How many of us would be clean and keep our children clean under such conditions? To take another instance, a recent inquiry has been made by the Local Government Board in thirteen industrial towns in the West Riding of Yorkshire as to the effect on health of living in back-to-back houses. According to the official report: "Even relatively good types of back-to-back-houses, when compared with through houses, have a death-rate from all causes taken together which is 15 per cent. to 20 per cent. in excess of the death-rate in through-houses." Yet not long ago it was shown that Birmingham alone contained forty thousand such houses. The evidence is clear that back-to-back houses should not exist. They are not fit for the most worthless part of the population of a State; and, indeed, we are careful to provide vastly better accommodation for our least valuable population.

The Fluctuations of Disease According to the Space Occupied by Families

The results are very clear when we compare the facts of overcrowding with the incidence of disease. Thus, when Sir George Newman was Medical Officer of Health for Finsbury, he showed that the death-rate in block dwellings varied in direct ratio to the number of rooms in the tenement occupied. For example, in 1906, the death-rate in one-room tenements in the borough was 39 per 1000; in two-room tenements, 22·5; and in three-room tenements, 14·8. The death-rate per 1000 from phthisis in the three cases was 3·4, 2·3, 1·4 respectively.

In connection with this supremely important disease, the greatest enemy that we have to face, it is worth while to quote a recent illustration. Everyone should know that consumption spreads rapidly through crowded tenements and workrooms. The nearness of the inhabitants is the first condition favourable to infection, and their low level of vitality is another, but we have lately learnt that the conditions of life of the tubercle bacillus are probably more important still. This microbe, which resists so many other agents, cannot withstand sunlight. In darkness and dirt it can flourish for many months, possibly years, between expectoration by one victim and inhalation by another. In such conditions as we are describing, it seldom has to wait so long. Thus the authors of the great new volume on "The Control

WOMAN THE HOME-MAKER DRIVEN FROM HOME INTO THE COMMON SHELTER

The insufficiency of house accommodation for the working people of our cities causes many daughters to leave home, and some, as here portrayed, drift down to the bare shelter of the soul-chilling common lodging-house

and Eradication of Tuberculosis" prepare a map typical of many streets in Edinburgh and elsewhere. In this "M—— Terrace" (the name of which should certainly be known), there are fourteen dwelling-houses of the kind which should not exist. They all contain cases of consumption, varying in number from one to seventeen, the total number of cases in the fourteen houses being fifty-eight. It might be supposed that such a case is unique, but it is not so. There must be an enormous number of just such streets, if we remember that we have something like half a million consumptives to account for at any moment in these islands.

The Close Connection between Consumption and the Shameful Housing of the People

It is perfectly clear already to students of this disease that the housing question must be primarily dealt with if it is to be overcome. As Professor Béraneck says, in his introduction to the volume cited above: "Before the actual cause of tuberculosis was known, it was recognised that this terrible malady was induced by concentrations of human beings, and by the usually deplorable hygienic conditions under which such concentrations are obliged to live."

But it has not yet been possible to demonstrate the facts to the public, or even to ascertain them fully, because the disease has not been notifiable. Since the first day of the present year, however, all cases of consumption occurring in England are required to be notified by the doctor. This means that, in a short time, it will be possible to compile, for the whole country, a consumption map as detailed as that of the Edinburgh terrace described above. The connection between this disease and the shameful housing of the people will then be conclusively demonstrated; and it is to be hoped that large sums of money, otherwise liable to be spent to little purpose against the disease, may instead be spent in the destruction of the plague-spots where it is bred, and where it will continue to be bred so long as they are allowed to exist.

The Question of the Immunity of Slum-Dwelling Jews from Slum Diseases

It is possible to approve most heartily of the principle, and much of the detail, of the consumption clauses of the National Insurance Act, and yet to know well that we shall yet come to recognise the systematic extirpation of plague-spots as more radical than anything those clauses effect. The relation between infant mortality and overcrowding, and notably between infant diarrhœa and back-to-back houses, is notoriously familiar to students of this subject. When they examine children at later ages, the facts are in tragic consonance with expectation. Thus, children of fourteen years old were lately compared in Liverpool and Port Sunlight respectively, with the result that the Liverpool children were found to be, on the average, five inches shorter and thirteen pounds lighter than were those of Port Sunlight.

At this point in our inquiry we may recall and deal with the theory, of obscure origin but much popularity, that in the course of time there is bred in the slums a slum-race which withstands and even thrives in its conditions. There *is*, indeed, one instance that, in a sense, lends colour to this theory. The modern Jews of the large cities of Europe and America may very nearly be called a slum-race; and nothing is more remarkable than their astonishing relative immunity to consumption, their low infant mortality, and the physique of their children, when compared with Gentile children of the same ages from similar conditions, as was shown some years ago by Dr. William Hall, in Leeds. But the breeding of this slum-race has taken many centuries, and has by no means been without serious physical and other disadvantages of its own.

The Evidence that Other Races have not Acquired Immunity from Slum Diseases

The case of the Jews only serves to demonstrate the shocking falsity of the theory as applied to our slum population at the present time. For what we find is that the slum population has *not* acquired immunity to the conditions of its life.

Any theorist may sit in his comfortable armchair, with no risk of infection and no intention of running any, and argue that "natural selection" in the slum would weed out those who were less fit for the conditions, and so gradually produce a race that could thrive in the slum. The answer to this argument in favour of doing nothing is furnished by the death and disease rates of the slum population. So far from thriving in these conditions, we find that they die in them; that from infancy to age they suffer. It will be time to congratulate ourselves on the evolution of a race that can stand the slum when we have evolved such a race.

But the fact is that, so far as our native slum population is concerned, other forces come into play which not merely make impossible the evolution of an immune

race, but directly cause degeneration of their own. This point is cardinal to the whole theory of eugenic practice as the present writer understands and advocates it.

For, as the reader may remember, we are to recognise, and in due course to study, certain agents which we have agreed to call racial poisons, on the ground that they injure not only the affected individual but the race, by their directly destructive effect upon germ-cells. Vastly more important, in this country, than all the other racial poisons put together are alcohol and venereal disease. If, then, it can be demonstrated that the shameful housing of the people, especially in our cities, directly conduces to alcoholism and to immorality, and thus directly to racial poisoning and destruction, the theory that the slum produces an immune race may be for ever abandoned.

The Connection between Bad Housing and Demoralisation by Alcohol

We note in advance that the exceedingly strict code of the Jews has always protected them, even in the slum, from these racial poisons. If confinement to the Ghetto, for centuries past, with no recruits from the country, had meant alcoholism and venereal disease for the Jews, they could not have survived it. Such, at least, is the evident fact in the writer's judgment. But, this race apart, we find, in the first place, that bad housing directly contributes to alcoholism. The public-house is the natural resort of the man whose own "home" offers neither comfort, nor peace, nor room for his limbs. To blame him is worse than pharisaic folly. As a recent writer has very happily stated it: "The only substitute for the public-house is the private house." It is profoundly true; and every student of alcoholism knows that, though this is not the solution of the whole of a very complicated problem, it is a great part of the solution.

The Degeneration of Italy under Slum Conditions and Alcoholism

It is doubtless true that drinking brings people into the slum, but it is also true that the slum drives people to drink, which becomes "the shortest way out of Manchester."

New evidence in this connection has lately been furnished us by Italy. It has been argued by Dr. Archdall Reid, who has persuaded many to follow him, that a nation can only become sober by long experience of alcohol, which gradually weeds out the susceptible, and leaves a sober race, by means of the great nineteenth century fetish "natural selection." In this argument the action of alcohol as a racial poison is obviously ignored, as in the case of all the other sham parallels to natural selection. Natural selection kills or spares; these kill or spoil.

But in any case observe the staggering refutation of this famous argument, advanced by Dr. Archdall Reid eleven years ago. His great illustration was the remarkable sobriety of the races round the Mediterreanean, Italians and others, who have had the grape and wine for long ages, and so have become immune by the killing off of the susceptible. But since he wrote there has been a great development of industrialism in Italy, an enormous influx into the towns, and a repetition of the conditions of overcrowding and atrocious housing with which we are familiar in our country. And lo, this immune race, in a decade, has become terribly afflicted with alcoholism, so that Italian statesmen of the first rank and of all parties agree in deploring it, as well they may, when the records of the last decade are examined.

This is not the place to discuss this question further, but we may rightly note that the Italian experience confirms, only too saliently, the view of observers at home, that overcrowding and bad housing very greatly predispose to alcoholism.

The Crowded and Insanitary House as a Source of Moral Infection

It is plain that there should be an alliance between the friends of temperance and the friends of good housing, and that we cannot cover the entire ground by such phrases as "the sin of intemperance."

As regards immorality and the racial poisoning which very frequently follows upon it, the facts are indisputable. Thus, in the Appendix to the Report of the Poor Law Commission, we read, in reference to the unmarried mothers in workhouses: "We believe that housing conditions must bear a large share of the blame for the fall of the women and girls who are thus made paupers. The shameful overcrowding of children of all ages, and the life in one room, allow of no training in elementary decency, much less in modesty and self-respect." As Professor William Smart, of Glasgow University, has put it: "There is no centre of material deterioration and infection worse than an insanitary house. There is no centre of moral deterioration and infection worse than a bad home."

This introduces a final question, which it behoves the Eugenist most carefully to

In populous city and spacious country alike, Science calls for better homes, where family life may flourish healthily.

consider, before he argues in favour of better housing. The Dean of St. Paul's has lately stated the antithesis: Does the pig make the sty, or the sty the pig? Speaking as an official representative of Christianity, he assures us that, in the judgment of Christianity, the pig makes the sty. The language strikes one as unfamiliar, especially as pigs are not kept in sties in Palestine, but it expresses the attitude of many Eugenists, at any rate, to this problem. They have found in it another argument for the slum.

Greatness Produced from Poverty, but from Slumdom—Never

We have already considered the argument that the slum breeds an immune race, and may therefore be left alone. The new argument is that worthless people, or "pigs," inhabit the slum and make it what it is. The forty houses with a single tap between them, in Manchester, seem relevant in this connection.

But let us observe the nature of the evidence upon which these apologists of the slum rely. At least two arguments may be noted. The first is that real worth will always show itself, and they point to the many and glorious instances where great men have arisen from conditions of poverty. The answer to this is twofold: first, that we cannot say how much potential greatness the poverty may have destroyed; and second, that we must not confuse poverty with the conditions of the slum. Many great men have come from poor homes, but the writer here repeats his challenge for a list of great men other than Jews that have come from slums. The first name on this list has not yet been supplied him.

The second argument of the pro-slum party is based upon the lamentable behaviour of slum people when they are transplanted. There is no doubt that the results are most disappointing—for those who suppose that any average person can live in a slum and not degenerate.

The Proofs of the Regeneration of Children when Taken Early from Slum Surroundings

Experience shows that when a slum area has been condemned, and the inhabitants have been removed to decent dwellings, they put coals in the bath and break the banisters for firewood. Hence it is argued they are *inherently* worthless people.

The inference is an inexcusable fallacy, which palpably assumes what must be proved—that the previous slum-life is not responsible for these people's behaviour. In one way the facts can be tested—by transplanting not the parents but their children.

The results are as gratifying in this case as they are depressing in the former case. We now have real experience on this point. The housing authority in Glasgow has transplanted large numbers of slum children. The Salvation Army and Dr. Barnardo's homes have transplanted many more. Mr. C. B. Fry has several on his training-ship, the "Mercury." These are authorities to trust—not those who have never been in a slum, nor stirred a finger for the human life that is being allowed to rot there. They agree in the verdict that the child from the slum does not grow up like its parents if it has been taken away early enough. Hence the crucial experiment, thus made on a large scale and in a variety of different ways, upon slum children is adverse to the view of the pro-slum party.

No; there is no defence for slums at all—not even that they afford opportunities for the fashionable virtue of "slumming." Not one man in a thousand born and bred in a slum—no, not one in ten thousand—can wholly resist its physical and moral influence. The vital statistics, if they should not be called mortal statistics, are conclusive against the theory of adaptation

The Heavy Toll Paid by all Human Society for the Existence of the Slum

Slums are the breeding-places of physical diseases, from consumption to the mere parasitic affections of the skin, which spread here and there through all ranks of society—the toll we pay for allowing such places to exist. They are the breeding-places of moral disease, from the characteristic listlessness, which is probably as much physical as moral, to forms of immorality which cannot even be named here. They are not needed for the extermination of the defective members of the race. Even if that argument were regarded as morally admissible, in point of fact we do not send our feeble-minded, insane, and grossly diseased population to the slums, but accommodate them in fine asylums and hospitals, and country colonies. On the contrary, the slums provide the conditions which actually originate degeneracy, as we have seen; and though they are well provided with lethal chambers—they have none other—these are not effective until the poisoned life has already been passed on, in many cases, to a new generation. The slums must go, and will go. Within the present century they will be blotted out from the living memory of man.

THE SUN THE LORD OF LIFE

The Mighty Voice of our Ruling Star Thrilling Through Immensity in Electrical Vibrations

WHAT WE THINK WE KNOW OF THE SUN

CERTAINLY astronomy has record of no greater achievement than the discovery that the sun is one of the stars. That discovery gives us a new conception of the universe. Further, the systematic comparison of the sun with the stars, notably as regards the quality of their light, teaches us far more fundamental facts about the universe than separate study of either could afford. We have everything to gain from the study of the sun as a star—as that particular specimen of the stars which happens to be under close observation, and from which we can learn, in large degree, what are the other stars, whose remoteness is so great. The sun is more than ninety millions of miles away, no doubt, but the *next* nearest star is at least twenty millions of millions of miles away, so that, relatively to any other star, the sun is under our immediate watchfulness. And the advances of spectroscopy, the analysis of light, are enabling us to classify the stars, and group the sun with certain others which conform to the particular type, and perhaps to the particular stage of evolution, which the sun exhibits. All this is the study of the sun with reference to the stars, and the new astronomy finds therein an infinite field of inquiry.

But, after all, the sun is *our* star, and we astronomers are human beings, born upon a satellite of the sun. Therefore the study of the sun in relation to our earth must certainly precede—in importance, as it also has done in the history of astronomy—the study of the sun in relation to the stars. We look at Sirius, or at the nebula in Andromeda, and they interest us intensely, and repay our study, but we cannot doubt that if Sirius, or any other star but one, or any nebula whatever, were at this instant to cease to be, the life of man would be wholly unaffected. They produce neither life nor death, sanity nor insanity; their movements and positions have no prophecies or warnings for the lives of men; their light suffices for us to see them by, and in some degree to study them by, but it neither warms nor illumines us, nor does it in any way affect our earth as a habitation for us. Our interest in them is therefore almost wholly theoretical, detached, academic, impersonal, to-day, and markedly contrasts with the feelings which animated our astrological forefathers, who studied the stars in order to know what should happen to them to-morrow.

The star we call the sun, however, sustains our lives, causes death, disease, drought, harvest, sanity, insanity, cures illness, and produces illness of the skin no less than of the brain; its changes affect the magnetic needles of our compasses; the cycles of its spots and storms can even be connected with the occurrence of fluctuations in wheat supply, in the statistics of suicide, and in the occurrence of trade disputes. Whatever the historical origin of the relation between the sun and ourselves, no matter whether it be our big brother, no matter whether our planet was originally captured by the sun, or was derived from a detached portion of the sun's exterior, it is certain that the existing relations between the sun and the earth are profound, numerous, indissoluble, and that they, beyond all other facts of the material world, condition the life of man.

We have used the word *numerous*, and must justify it. The older astronomy centred its interest, inevitably, in the gravitational relation between the earth and the sun. After all, not many generations have passed since man discovered that his earth revolves round the sun, and that this revolution is controlled by gravitation. That single fact can be, and has

been, extended, so as to build what has often been called a gravitational astronomy, and there is no end to the investigations which it must pursue. If we are about to insist that, in a sense, that is only the beginning of the study of relations between the sun and the earth, we must not underrate its importance. On the contrary, let us acknowledge that the extensions of the purely gravitational astronomy of sun and earth still promise new things, not least as regards poor, neglected meteorology, "the Cinderella of the sciences."

Let us briefly note, then, what this single gravitational relation involves. First, it explains and conditions the earth's annual revolution in its orbit. But that is only the beginning of the problem, for gravitation does not act between the sun as a whole and the earth as a whole. The law of gravitation asserts that every particle of matter in the universe attracts every other particle with a certain force. All the sun is thus pulling on every individual atom that composes the earth, *and vice versa.*

How the Gravitational Power of the Earth Raises Tides on the Sun

No matter, then, what the sun and the earth are made of, their gravitational action on each other must be very different from that which astronomers have so long assumed—the action of two imaginary points pulling on each other at a certain distance and with a certain force. The sun and the earth react gravitationally upon each other's parts.

Up to a point there can be no doubt of this, for we know that the sun raises daily tides upon the oceans of the earth, as they are rotated in succession towards and away from the pull of the sun. And we already know that these sun-raised earth-tides, as studied especially by Sir George Darwin, are bound, in the course of ages, to produce notable effects in the movement of the earth as a whole. But, as Galileo first found, when his telescope revealed the sun-spots and their passage across the solar disc, the sun rotates upon its own axis, just as the earth does, and, as we know, in the same direction. But this must mean that the earth raises tides on the sun; and these earth-raised sun-tides are special consequences of the gravitational relation between earth and sun, which will have large results for the Solar System as a whole some day.

Many who read of these effects of the earth upon the sun for the first time feel incredulous, for they are long accustomed to the idea that gravitation is something by which big bodies bully little ones—the sun pulls the earth, the earth pulls an apple, and so forth. But gravitation is always and necessarily a mutual thing. When the apple falls to the earth the whole earth also rises to the apple in a tiny but necessary degree; and, just similarly, while the sun attracts the earth so also does the earth attract the sun. If the sun be rotating under this influence then successive portions of its surface will successively come nearer to the earth, will be more affected by its pull, and thus tides will be raised upon the sun, just as the sun raises tides upon the oceans of the earth which are for ever rotating under its pull.

The Unrealised Fact that Tides may be Gaseous or Solid as well as Liquid

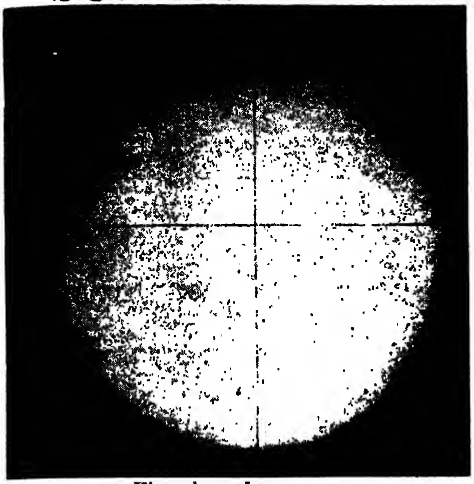
The sun has no water of any kind, much less water so cool as to be liquid and form oceans. But that matters not at all. It is only our conventional thought which assumes that tides must always be in liquids. Tides depend upon gravitation, and all matter exercises and is exercised by gravitation. Hence, where liquid matter comes under tidal action, as in our oceans, we have liquid tides, but where gaseous matter is concerned, as in the atmosphere of the sun and the atmosphere of the earth we have gaseous tides; and it has lately been possible to demonstrate the existence of the solid tides, in the crust of the earth which are raised by the sun and the moon and which astronomers were bound to expect and assert long before instruments clever enough to detect them could be devised.

London Itself Raised and Dropped Several Inches by the Attraction of the Sun

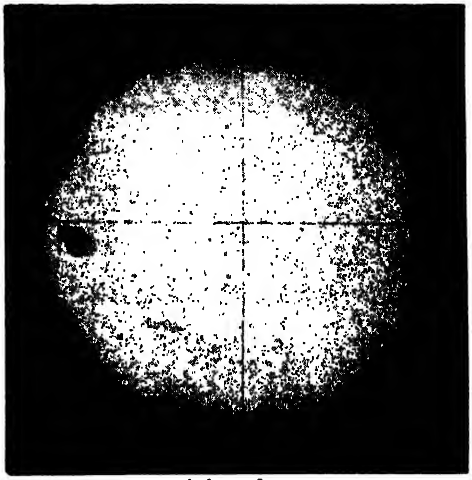
Thus, such a mighty metropolis as London, with all its buildings and inhabitants, is ceaselessly being lifted bodily upwards, and then dropped again, a distance of several inches, by the gravitational action of the moon, and to a less degree by that of the sun, as the earth rotates London under their respective pulls; and these tidal, rhythmical deformations of the crust of the earth must in due course affect the rotation of the earth and the destiny of the Solar System.

We have alluded to gaseous tides, the atmospheric tides raised on the sun by the earth, and raised on the earth by the sun and the moon. Here is a subject which is practically new, and about which little can yet be said. But there can be no doubt that it is fraught with enormous significance for the problems which meteorology has

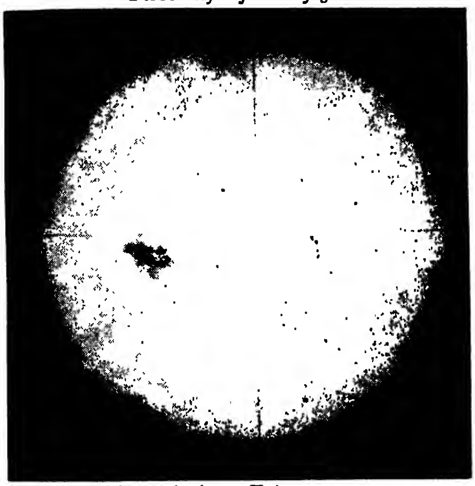
SUN-READING BY PHOTOGRAPHY



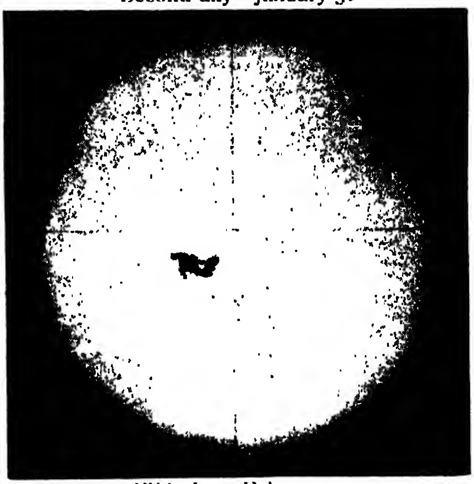
First day—January 30



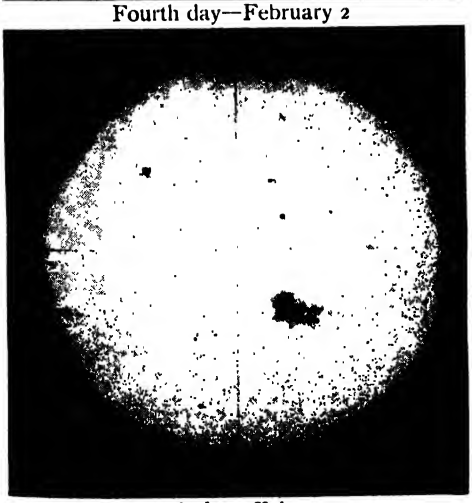
Second day—January 31



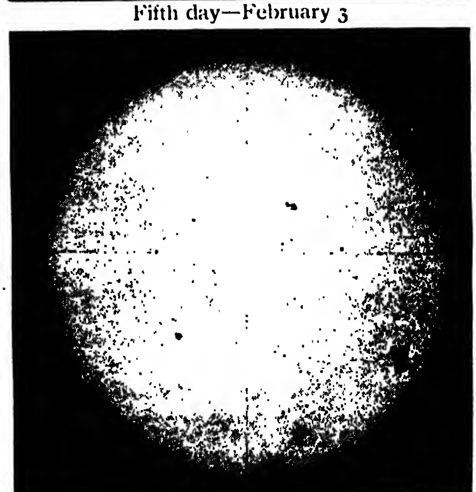
Fourth day—February 2



Fifth day—February 3



Seventh day—February 5



Tenth day—February 8

TEN DAYS' PHOTOGRAPHS OF SUN-SPOTS IN 1905, SHOWING THAT THE SUN REVOLVES

These beautiful photographs, taken at the Royal Observatory, Greenwich, are reproduced by permission of the Astronomer-Royal

so long been trying in vain to solve. The questions of climate and weather do not here concern us, but we are bound to observe that the general gravitational influence of the sun upon the earth extends in such ways as these to the most intimate and seemingly local details of the immediate environment of man.

Lastly, in leaving this summary of the facts which depend upon the gravitational relation between the earth and the sun, we may permit ourselves, for a moment, to consider what would happen if, at any given instant, this invisible bond between sun and earth should cease to exist. Following Newton's first law of motion, the earth would immediately leave its elliptical orbit at a tangent according to what used to be called "centrifugal force," and would move further and further from the sun. It would cross the orbits of the outer planets, and, assuming that it escaped their influence, would soon pass into outer space.

Only as Captives of the Sun can We be Free to Live

The conditions of the earth's surface change in just the opposite direction would be that described by the great American astronomer Professor Simon Newcomb, in a popular account of the approach of some imaginary star to the Solar System, on its way to a collision with the sun. In that case the earth's surface would become hotter, with results soon fatal to mankind and to all forms of life. But if the gravitational bond between the earth and the sun were annulled, and the earth, leaving the sun, were to become steadily cooler, the results would be just as disastrous. Marvellously adaptable as terrestrial life is to the conditions of the earth's surface, it could not survive any such changes as would follow if the earth left its orbit. This is the answer to the speculation put forward a few years ago by M. Maeterlinck, that within a few centuries man might be able to control gravitation, and take his planet where he pleased. The best place for our planet is where it is, if we wish to survive upon it; and hence the force of gravitation, which swings the earth in its orbit round the sun, conditions our existence. Only captive to the sun are we free to live.

We have already seen that the most advanced thought of our time is inclining to regard gravitation as electrical in Nature. However that may be, it is certain that the sun is a centre of tremendous electrical force, which is of the utmost importance for our planet. Whether or not the force is akin to gravitation, as may be, whether or not it is conveyed through the same ether which conveys gravitation, as doubtless must be, at any rate it is no less important a fact of the sun than gravitation itself. The real meaning and potency of the sun, indeed, is expressed in these two ways: the sun is a centre of gravitational and of electrical force, in relation to the earth.

The Sun as a Great Reservoir of Electrical Force

Perhaps the reader may scarcely have realised that, when we speak of the electrical force of the sun, we are simply describing, in the modern language of science, the two facts of the sun's power which mankind has been familiar with from the earliest ages—its light and its heat. If our statement and understanding of the sun is to be abreast of modern scientific ideas, and is to make us prepared for future discoveries, such as the astronomers' "international attack upon the sun" will surely provide, we must accustom ourselves to "think electrically"—if a famous phrase may be adapted to the present purpose. The interesting facts of sun-spots, and the great solar flames seen during total eclipses of the sun, are important in helping us to understand the electrical condition of the sun; their picturesqueness is undeniable, but what modern science cares about them for is the help they may afford in the task of unravelling the physics of the sun. For we are beginning to be able to sort things into their places, and putting those together which are really the same, and the result of the process is to teach that the sun really matters to us, and is interesting in itself, above all, because it produces electrical force.

Light and Heat Products of the Sun's Electrical Powers

It has already been noted that changes in the condition of the sun affect magnetic needles on the earth. We shall realise better the reasonableness of this when we remind ourselves that light is now known to be an electro-magnetic disturbance in the ether. Radiant heat, also, is nothing else; and thus the light and heat of the sun are the products of its electrical powers. This means, for the student, that in the middle of his study of astronomy he is compelled to turn aside, as it appears, to investigate the nature of light and heat, which seem to have nothing in particular to do with the study of the heavenly bodies. But the reader must not object. He is

only being compelled to do what all the astronomers have been compelled to do before him. They have long studied the sun, in the ordinary astronomical ways, to ascertain its distance and size, and so forth, which we shall look at soon, but within the last decade they have all been compelled to turn to what is now called Solar Physics, to make new instruments and build new observatories for the minute study of the light and heat of the sun, because to study them, *here*, is indeed the profoundest way of studying the sun, *there!*

In other words, the study of light and heat has come into astronomy, and has become as essential a part of astronomy as the study of gravitation. If all three are electrical facts of the universal ether, need we be surprised? What we now assert of the study of the sun is no less true of the study of the stars, and, indeed, what is generally called the "new astronomy" depends entirely upon what we learn by studying the light and heat of the sun and the stars, in order to find out not *where* they are, which was the task, in the main, of the last generation, but *what* they are.

That vast centre of electrical force which we call the sun is continuously pouring into space, on all sides, a quantity of electrical waves, as we now name them for convenience, to which we have long given other names, not according to their nature, but according to the particular sense-organs by which our bodies appreciate them. If the retina of the eye is affected by any of these electrical radiations we give them the name of light. If the nerves of heat in the skin are affected by any of these electrical radiations we call them heat. If we have no senses which can be impressed by any of these electrical radiations, we are unaware of their existence until special devices discover them —and then we hardly know what to call them. But whether visible or invisible, hot or cold, bright or dark, red or violet, "infra-red" or "ultra-violet," these rays are all fundamentally identical. All are electrical, all are simultaneously produced by the electrical state of the sun, and travel together, at equal rates, throughout space. The confusion in our minds, our ignorance of some, and familiarity with others, and the sharp distinctions we make between them, are simply due to the limitations of our senses; and until our minds can overcome this difficulty made by our bodies, any scientific understanding of these matters cannot begin.

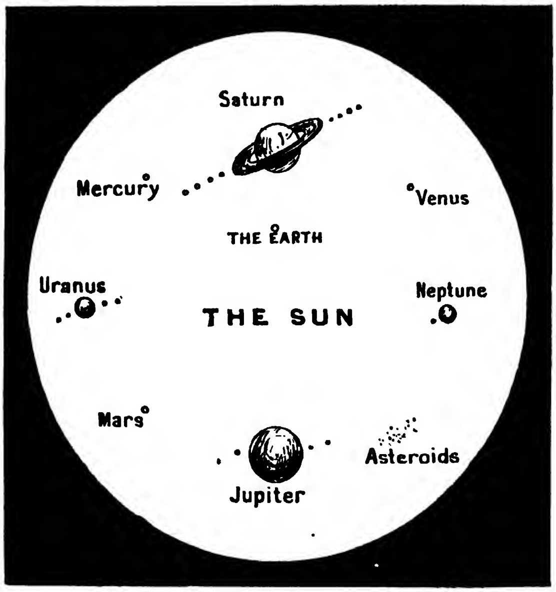
THE FAMOUS TIDAL BORE AT MONCKTON, NEW BRUNSWICK

If all the keys of a piano were struck simultaneously, a vast multitude of sound-waves, long and short, would be thrown through the air. That company of waves gives a very inadequate idea of the great gamut of waves, all electrical and fundamentally similar, which the sun is always sending into space. The comparison is inadequate for a very precise reason. Each key of the piano corresponds to a special string, which produces waves of a special length. The strings next above and below represent a certain gap or "musical interval" between waves of one size and waves of another. The piano cannot produce waves between those of, say, A and A sharp. But, of course, such waves exist, as we hear to our distress when a singer, trying to sing A sharp, sings

something which is not A sharp nor yet A, but something between them. For the purposes of music these intervals must exist, and the piano and all other keyed instruments are made accordingly. But the "full compass" of the sun's waves is full indeed, for it has *no intervals*. The electrical waves it produces are of *all* lengths, by infinitesimal gradations, from the lowest note of its compass, so to say, up to the very highest; and the sun utters all these notes at once.

Astronomy and many other sciences would be in a vastly more advanced condition if the body of man were so made that it could somehow "sense"—one cannot say "see" or "feel"—the whole of the sun's electrical compass, just as the ear can hear the whole of the compass of the piano. There are aerial vibrations below those which the ear can hear, and others above the highest we can hear. As for the compass of the sun's vibrations, we have two senses, vision and the thermal or heat sense, which we can, so to say, join end to end, and between them they afford us direct knowledge of all of the sun's rays that men knew until a few years ago. But now we know that, even when the rays of radiant heat and the rather higher-pitched rays of light have been recognised as lying next each other in the compass of the sun, there reaches downwards a long range of radiations which are "cool"—that is, unfelt by our nerves of heat; and upwards a long range of radiations which are "dark"—that is, unseen by our nerves of vision.

We stand in the sun and feel its heat and see its light. We cannot distinguish the notes, so to say, of the sun's heat, yet the compass of solar radiations, all of which strike our nerves as heat, is really a long one, and some of the most important advances in solar physics are being made by the study of this dark but warm part of the spectrum, and of the part, lower still, towards the bass of the sun's mighty voice, which is not less dark, but is not even warm at all. The waves down here are usually called electrical, simply because they can be detected by electrical means, and none other, but they are neither more nor less electrical than the higher-pitched waves, of shorter wave-length, which our senses recognise as heat, and those, higher-pitched and shorter still, which they recognise as light. Beyond the upper limit of vision we can now recognise, by the mind's eye, interpreting the records of specially made instruments, a long series of "ultra-violet rays" which are of the utmost value to the astronomer, not only because of what they promise to teach us about the nature of the sun that utters them, but also because they powerfully affect many sensitive surfaces, other than that of the retina of the eye, and so afford us photographs of the sun, and of the many other heavenly bodies which also produce rays of this particular type.



THE RELATIVE SIZES OF THE SUN AND THE PLANETS

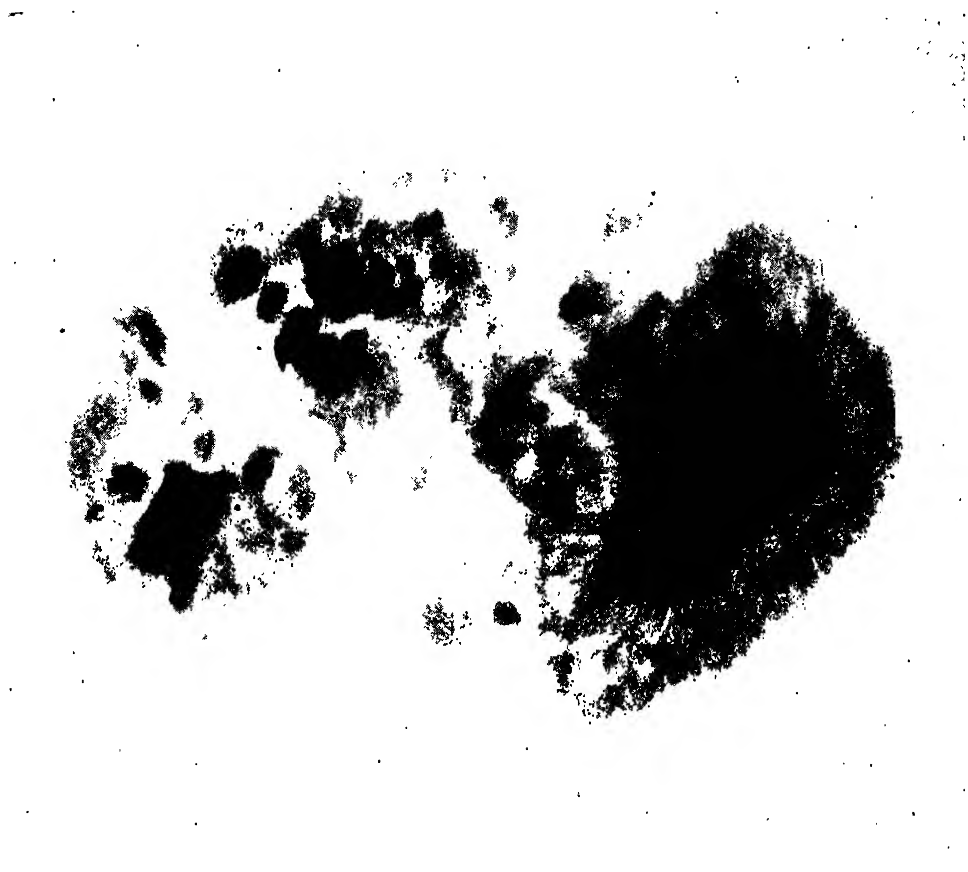
Just as the nerves of heat simply give us more or less of one undifferentiated sensation, so the eye gives us more or less of the "white light" of the sun, when we stand in the daylight. But this white light really covers no less important a series of gradations, in the radiations which our eyes thus interpret, than the gradations in the series of heat rays. That is why the whole landscape of science has been illuminated, ever since, by a tiny ray of light which Newton admitted to his darkened room through a hole which he had cut in the shutter. Opposite the hole, in the path of the beam, he placed a prism, and on the opposite wall he saw a band of colour, red at one end and violet at the other, which we call the spectrum of sunlight. White light, then, is a chord of several notes—really an infinite number of notes—and the prism breaks the chord up into a band of colours, like an

octave of keys upon a piano, because the rays are differently bent as they pass through the glass, according to their wave-length, and are thus thrown side by side, instead of being superposed, blended, and indistinguishable, upon the screen which receives them.

Extend and amplify that prism, provide specially suitable surfaces for the different parts of the spectrum to fall upon, place thermometers in the various parts of the beam, and in the dark areas, on either side, where the real beam extends, test the action of magnets upon the beam, compare the details of it with those of light from other sources, from a candle and a star and a glow-worm, and you are simply repeating and adding to the experiment of Newton, in the practical branch of science now called spectroscopy, or spectrum analysis, which may one day hang a murderer by detecting the changes produced by prussic acid in the colour of blood, and the next day may tell us the chemistry of Sirius or the magnetic behaviour of a sun-spot. Only a prism, through which you can see nothing clearly; yet through it man has seen further into space, deeper into the atoms of the sun or of his own blood, than all the telescopes and all the microscopes in the world had ever, and can ever, avail him.

It is this spectroscopic view of the sun which now dominates astronomers, and it is the physics and the chemistry of the sun that now engage their attention beyond everything else. These hold in them the key not only to the sun, but to the stars; not only to sun and stars, but to the history, and perhaps the destiny, of bodies no longer radiant, such as our own earth. We peer into the sun with a prism in order to see the hidden depths of the earth.

But first, in a few paragraphs, we may rehearse the main telescopic facts of the



A SUN-SPOT, A FACTOR THAT MAY HELP IN UNRAVELLING THE PHYSICS OF THE SUN

From a photograph taken on July 31, 1906, at the Royal Observatory, Greenwich, and reproduced here by permission of the Astronomer-Royal.

sun, to which the work of the nineteenth century was so largely devoted. This is not to say that the work has been finally done. Every new estimate of the size, the mass, the distance of the sun will be different from the last, not merely because of what astronomers call the "personal equation" of the observer, but also because much depends upon the method employed, and because no degree of astronomical exactness is ever final.

The Impossibility of Securing Final Accuracy in Measuring and Weighing the Sun

These considerations deprive the "latest estimates," in astronomers' eyes, of any unique importance; astronomers know that these latest estimates will soon be superseded. The scientific value of the various results depends not upon the results themselves, but upon the study and understanding and comparison of the particular methods employed; and there, where the really technical and educational value of the subject begins, the interest of most students is apt to end. Let us therefore not pretend to be more accurate than we really can be, and let us aim especially at the one object that can be attained—which is to obtain sound general conceptions of the magnitudes which we are to consider.

The accompanying diagram, worth many rows of figures for the present purpose, indicates the comparative dimensions of the sun and the earth with Jupiter, the giant of the planets, and the other planets in their relative sizes. To state a dimension in precise figures is simply to mislead, for the sun has a great gaseous envelope, of gradually diminishing density; and who shall say at what point the sun ceases or begins?

Comparisons that Give an Idea of Sizes in the Solar System

If we note that the diameter of the sun is somewhere about 865,000 miles, the reader must particularly beware of supposing, from the numbers, or from the sharp outline of the figure of the sun in the diagram, that the sun has a surface like the surface of the earth—which, in any case, is not the surface of the earth, but only the level at which the solid and the gaseous parts of the earth succeed each other. To determine the real surface of the earth we should have to ascertain where the atmosphere ends, scores of miles above our heads; and the sun has no such solid surface, at any level of its substance, as the earth has.

The size or volume of the sun, and its mass, are, of course, two different things, which must never be confounded. So far as size, bulk, or volume is concerned, we might cut up the sun into more than a million pieces, each of which would be larger than the earth. But the mass of the sun is not proportionately greater than the mass of the earth. By mass we mean, of course, the amount of matter in anything, and that is what we want to determine for the sun. We cannot speak of the sun's weight, be it noted, for weight is simply the result of gravitation; and if gravitation ceased, nothing would have any weight, but the mass, the amount of matter, in things would remain. Now, the matter composing anything may be lightly or loosely packed. Generally, the rule is that the matter of hot things is more loosely packed: heat expands them; and so we may expect the intensely hot sun to be, on the whole, very much less dense than the earth.

That is indeed the case; and though the sun is more than a million times as large as the earth, it is only some three hundred thousand times as massive or "heavy." But though "heavy" conveys the idea, the word is dangerous to use, for it conveys the notion of weight, which depends on gravitation, which varies with distance, whereas the amount of matter in a thing is the same, of course, whether we study it near or from afar.

How the Density of the Material of which the Sun is Composed is Estimated

What we call the *density* of any body expresses the relation between its volume and its mass—the smaller the volume into which its mass is packed, the greater is its density, and *vice versa*. In science, the density of water—under certain stated conditions of temperature and pressure—is adopted as a standard of comparison. Taking the density of water, then, as unity, or one, we find that the earth as a whole (including, of course, its water) is about five and a half times as dense as water—or five and a half times as "heavy," in popular language, as a similar volume of water would be. But the density of the sun, as compared with that of water (1·0) and the earth (5·5) is only about 1·4, if, indeed, it is quite so much.

Such a figure, of course, only represents the density of the sun as a whole—its mean density. But gravitation is at work between the particles of the sun, pulling them together, and hence the weight of the outer parts of the sun, or any other such body, presses upon its inner parts, and the density of the sun, as of the earth, must increase, steadily on the whole, from its

surface to its centre. The outer parts of the sun, consisting of rare hot gases, are, of course, far less dense than water, but the density of the interior of the sun, where the effects of the mutual gravitation of the particles composing its gigantic mass are fully displayed, must be enormous.

The Unimaginable and Uncalculated Temperature that Must Exist at the Sun's Core

Indeed, astronomers and physicists find it very hard to imagine what the state of matter can be in the centre of so huge and so hot a body as the sun, where a tremendous temperature is making for expansion and a tremendous pressure is making for compression, both such a temperature and such a pressure being far beyond anything which we can experimentally produce and study on our earth.

The temperature of the sun is no less interesting than its volume and its mass, but it is not easy to ascertain. We know it must be very high, and can scarcely believe—what is, nevertheless, the fact—that Newton seriously discussed the possibility that the sun may be inhabited. Nothing that we can conceive as life could exist at the lowest of the many estimated temperatures of the sun. Unfortunately, the figures given by astronomers vary so widely, and depend upon so many doubtful assumptions, that nothing definite can be stated. Further, the recent work done in the spectroscope has shown that various levels in the substance of the sun vary in temperature, and it is supposed that violent local phenomena also change the temperature of the sun in various places from time to time. But the figure of 30,000° centigrade, which has been estimated, or even that of only 9000°, which is another estimate, will suffice to show how hot the sun must be.

The Sun too Hot to Burn—the Chemical Combinations of Combustion being Impossible

Father Secchi, a great authority, made an estimate which was many hundreds of times higher than the higher of these two figures; and to fix upon any of these estimates as the right one would be absurd.

For the present we must be content to know that the temperature of the sun is, at the least, so high that, first, none of the complicated compounds necessary for the development of living matter could exist in it; and, second, not even the simplest and most stable compounds, such as water, carbonic acid, or sodium chloride (common salt) could exist in it. At the temperature of the sun even such compounds would be broken up into their elements. All the elements composing these compounds exist in the sun, as we shall learn later, but they exist uncombined, and the chemistry of the sun is a chemistry of elements, though not exactly elementary chemistry.

The amount of heat given out by the sun is a quite distinct measurement from that of the sun's temperature, and the study of it raises the further question as to its source. This is itself a matter which might be discussed in a large treatise, but we can already make one definite contribution to it from our knowledge already gained. If the sun is so hot that no compounds can exist in it, then the process of combustion, which produces heat in our furnaces on the earth, cannot occur in the sun, for combustion is the formation of compounds between oxygen and other elements, such as hydrogen and carbon. But water and carbonic acid, the respective products of such combustion, could not be formed at the temperature of the sun. We know definitely, then, even at this stage, that *the sun is not burning.* The source of the amazing output of electrical energy which we call the radiant heat and light of the sun is not combustion, whatever it may be.

The Figures of the Sun's Distance from the Earth Constantly Revised

One other figure we may conclude this chapter by stating. How distant is the sun? That question, which astronomers have so long asked, needs restatement. The earth revolves round the sun in an elliptical orbit. Therefore what we should ask is what is the mean distance of the earth from the sun, its "average distance" in popular language? This is a figure which astronomers are constantly revising, and some new work done with the help of the minor planet Eros is now leading to its further revision. But, according to the most recent authority, the mean distance of the sun from the earth is 93,100,000 miles; and, since exact figures do satisfy the mind, we may add those of the other magnitudes already here discussed. According to the computations in question, the diameter of the sun is 866,300 miles, and its mass is 334,500 times that of the earth.

One other figure requires to be added. The sun rotates upon its own axis. The earth's rotation occupies twenty-four hours, which we call a day. The sun's rotation occupies twenty-five such days, but the figure varies from the sun's equator to the poles, and probably from the surface to the centre, for the sun is not a solid but a gaseous body. Such, then, are the chief numerical facts of the "orb of day."

THE WAIMANGU GEYSER, IN NEW ZEALAND, FLINGING BOILING WATER 1500 FEET ALOF

The photographs on these pages are supplied by the New Zealand and Australian Governments, Messrs. Hinkins and Son, and Lieut. F. E. Bagger.

THE WONDERS OF WATER

Where It Comes From ; How It Was Made ; and Why It Varies in Its Composition

TESTING THE DIFFERENT SEA WATERS

It is an amazing thing that the hard, stony earth should be encircled by that curious collection of nimble gases known as the atmosphere Almost more amazing is it that the world should carry its wonderful burden of that substance known as "water," and should carry it in three shapes—as gas, as liquid, and as solid. Practically, all other things about the surface of the earth are solid, but the atmosphere remains gaseous, and the water hesitates in an unstable condition of betwixt-and-between.

The temperature of the earth has fallen a good many thousand degrees since the crust of the earth was molten, and now a fall of a few degrees more would freeze the ocean. A fall of a few degrees more, and on the frozen ocean would ripple a sea of liquid air. A fall of a few degrees more, and everything would be solid together. The difference between a world with balmy breezes and rolling seas, and a world with neither atmosphere nor ocean, is only the difference of a few degrees Fahrenheit. Fortunate it is that air and water are the last to solidify; fortunate it is that they were there to be last, for without them the world would be a shrivelled, dry mummy, like the moon.

Water is a particularly surprising phenomenon. It is a compound of two gases, hydrogen and oxygen, and it is a compound which does not form spontaneously. How, then, does it happen to occur in such large quantities ? It is true that all the water on the world only wets the earth in proportion to its size as an apple is wet by a misty rain, but it required a vast amount of the gases to produce even so much moisture. How, then, is there so much of it ? Where did it come from ? When did it come ? These are interesting, difficult, inevitable questions.

One thing is certain, that is, that when the crust of the earth was hotter, any water there might be then must have existed in the form of vapour. The great basins of liquid water are the ocean beds, but until the crust of the earth had cooled for thousands of years the ocean beds could have held water no better than a red-hot frying-pan. Were, then, all the oceans once up in the air ? Did the sea-water and the Polar ice, and all other water, originally form a huge atmosphere of vapour ? No; we cannot believe that. The sea as gas would have 1700 times its present volume, would have formed an atmosphere thousands of miles high, and the earth could not have retained such a voluminous and volatile atmosphere. Even if the earth could have held such a vast atmosphere of water-vapour, we should still have to explain where the water-gas came from, and how the compound was formed.

We surmount the difficulties and obtain a plausible answer to the problem only by assuming, as we assumed in the case of the atmospheric gases proper, that the water-vapour was formed not all at once, but by degrees, so that at no time did the earth's atmosphere contain more water-vapour than the earth's gravitative power could grip. Good! But *how* was the water-vapour gradually formed ? How was this marvellous compound of hydrogen and oxygen produced ?

There are two or three possible sources of water-vapour. In the laboratory we make water by passing an electric spark through a mixture of hydrogen and oxygen. Now, it is probable that, in the early volcanic days of the earth's existence, hydrogen was belched forth by volcanoes in great quantities; and it is probable that in the same early days lightning-storms were more violent and more frequent than now, and so it is quite likely that the lightning, as it

flashed through the atmosphere, combined oxygen and hydrogen into water. So much water, then, would be formed in the atmosphere by lightning, and would gradually condense as opportunity offered. That would be a worthy birth of this wonderful substance—to the flash of lightning and the roar of thunder, from the flames of volcanoes.

But a more important factory of water would be the bowels of the earth, and from this factory water would be sent to the surface ready-made. Meteorites contain, among other gases, hydrogen; and there can be no doubt that there was hydrogen in solution in the molten crust of the earth, and that a considerable quantity of hydrogen must have been stored subterraneously.

How in All Likelihood the Ancient Volcanoes Threw Up the Oceans

Under the right conditions of temperature and pressure the hydrogen would take oxygen from the ferric oxide of the earth's crust, or join any free oxygen it could find, and form water, and this water would reach the surface of the earth by means of hot springs, and geysers, and volcanoes. Probably volcanic steam is the chief source of water, and possibly volcanic steam alone suffices to account for all the water in the world. What a pretty paradox is this—water, the extinguisher of fire, made by fiery volcanoes!

The amount of steam discharged by a volcano is surprisingly large; and in the early days of the world volcanoes were probably much more numerous, and volcanic action was probably much more vigorous. How vigorous volcanic action may be, and how much gas the world-substance once contained, the mighty mouths of the moon's craters still testify. It is noticeable that all the great seas are ringed by volcanoes; and how many volcanoes may have formerly been spouting and snorting in the bed of ocean, who can say? Certainly the volcanic islands in the Pacific suggest violent volcanic action.

The Story Told in Corroboration by Volcanic Dust Flooring the Ocean Beds

Suggestive, too, of volcanic action is the volcanic dust found everywhere in the abysmal depths of the sea. It is true that this dust is usually supposed to have sunk through the water; but why, then, is it found only or mainly in the deep sea? It is quite as likely that it is the product of the same submarine volcanoes whose steam condensed as ocean water. Altogether it is not difficult to believe that, in one way or another, water is of volcanic parentage.

Having now found a source of the water of the earth, let us look at some of its properties. A most paradoxical substance is water. It is a compound of oxygen, a gas which supports combustion, and of hydrogen, a gas which burns, and yet it will not support combustion, and will not burn. Again, both oxygen and hydrogen are most difficult to liquefy and solidify, and yet at ordinary temperatures water changes from liquid to solid, from solid to liquid, with great facility. As gas we find it constantly in the air; as snow and ice we find it wherever the temperature falls to about 32 degrees Fahrenheit; and as liquid we find it, at some time or other, in almost every part of the world. Whether as gas, liquid, or solid, it plays unique parts in the economy of Nature.

One of the most unique characters of water is its capacity for heat. It has greater capacity for heat than any other known substance. That is to say, heat can be imparted to it in greater amounts without raising its temperature. On the same fire, under the same conditions, an ounce of mercury will grow as hot in half a minute as an ounce of water will grow in an hour. As a consequence of its heat capacity, hot water takes a long time to grow cold; and this and some other related properties of water have an important bearing on the question of climate.

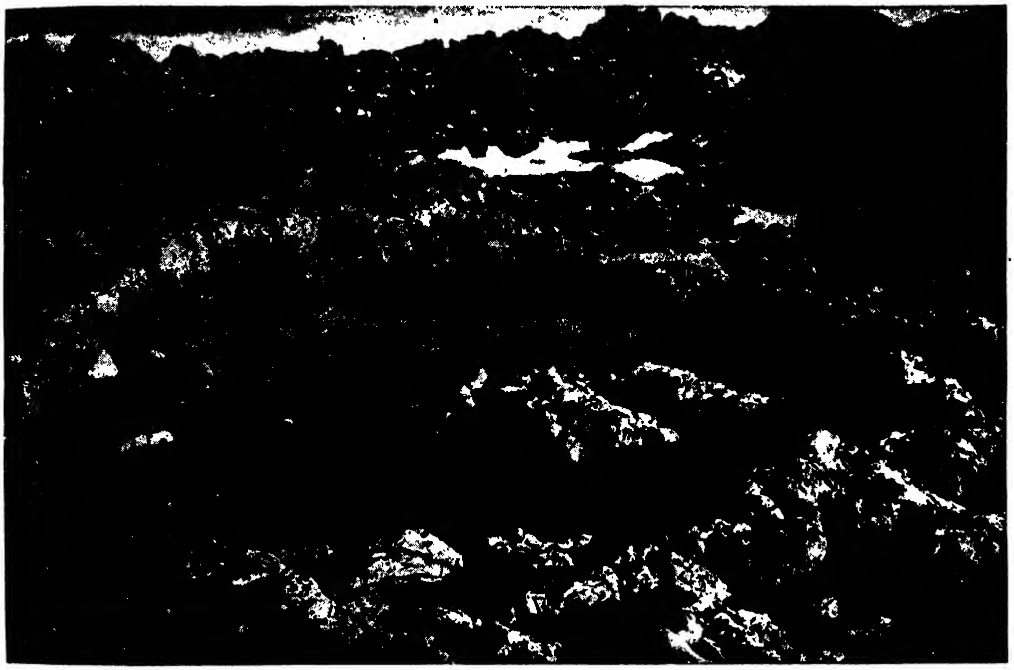
Climatic Effects of the Unique Capacity of Water for Heat

Wherever land is surrounded by sea, or near the sea, the climate tends to be more equable than inland. Not only does the vapour the sea gives to the air act as a parasol by day, shielding the earth from the hot sun, and as a blanket at night, returning to the earth the heat that would otherwise radiate away, but this capacity of latent heat which we have mentioned has an even more marked effect in preserving an equable temperature. For since the sea requires much more heat to warm it than the land, it is like a cool wet cloth on the hot land in great heat; and, again, since it stores up great amounts of latent heat, it gives this to the land if the land be cooler than the sea. A pound weight of water requires as much heat as four pounds of air to raise its temperature one degree; and thus one pound of water can raise four pounds of air one degree at an expense of only one degree of its temperature. Also, air is seven hundred and seventy times as light as water, and hence one cubic foot of water, by surrendering sufficient heat to lower its temperature one degree, can

raise one degree in temperature no less than three thousand and eighty cubic feet of air. When we come to talk of climate we will return to this topic.

It requires a great deal of heat to raise water from 32 degrees Fahrenheit (freezing-point) to 212 degrees Fahrenheit (boiling-point), but in order to convert it into vapour a great excess of heat, over and above the heat required to raise it to boiling-point, is required. To raise one pound of water from 32 degrees Fahrenheit to 212 degrees Fahrenheit requires 180 times as much heat as is required to raise it 1 degree Fahrenheit (*i.e.*, requires 180 so-called *heat-units*); but to convert the water at 212 degrees Fahrenheit into steam at 212 degrees Fahrenheit requires no less than 967 heat-units, or more than five times as much heat as is required to raise the water to boiling-point from freezing-point. All this heat applied to the water and supplied to the steam does not raise the temperature of the steam, and it is therefore called *latent* heat. The latent heat in the steam becomes manifest again when the steam is condensed; and one pound of steam passed into four pounds of water at 32 degrees Fahrenheit will, as it condenses, give off enough latent heat to raise the whole five pounds of water to 212 degrees Fahrenheit.

Suppose, now, heat is applied to ice, what happens? We find that if the ice is at 0 degrees Fahrenheit, each heat-unit will raise it 2 degrees, so that 16 heat-units will raise it to 32 degrees Fahrenheit. Ice is therefore twice as easily heated as water. But to convert the one pound of ice at 32 degrees Fahrenheit into water at the same temperature no less than 144 additional heat-units are required. Here, again, the heat is not shown as temperature, but is *latent;* and here, again, the latent heat will become manifest if the water again freezes. This alternate absorption and radiation of heat by water as it changes its state is one of its most characteristic features, and fits it for the part it plays in transmitting and regulating natural energy.



CRATER ON A VOLCANIC ISLAND THAT APPEARED NEAR TRINIDAD IN NOVEMBER, 1911

A very remarkable anomaly of water is that its volume at 32 degrees Fahrenheit is 8 per cent. less than the volume of the same weight of ice. Thus water in freezing contracts; and if we examine the behaviour of water as it cools down towards freezing-point we find that down to 39 degrees Fahrenheit it contracts as it cools, just like ordinary liquids, but that below 39 degrees Fahrenheit it strikes out a line of its own and begins to *expand* as it cools. The expansion at freezing, therefore, is merely a continuation of the expansion that began at

39 degrees Fahrenheit. In consistency, of course, when ice melts it contracts, and if the ice-water be heated it continues to contract up to 39 degrees Fahrenheit. It is not the thaw, accordingly, that bursts the water-pipes; the pipes may burst as the water cools, at any point below 39 degrees Fahrenheit. but if they have stood the expansion of freezing they are not likely to burst with the contraction of cold. Above 39 degrees Fahrenheit water expands with heat and contracts with cold, just like ordinary orthodox substances.

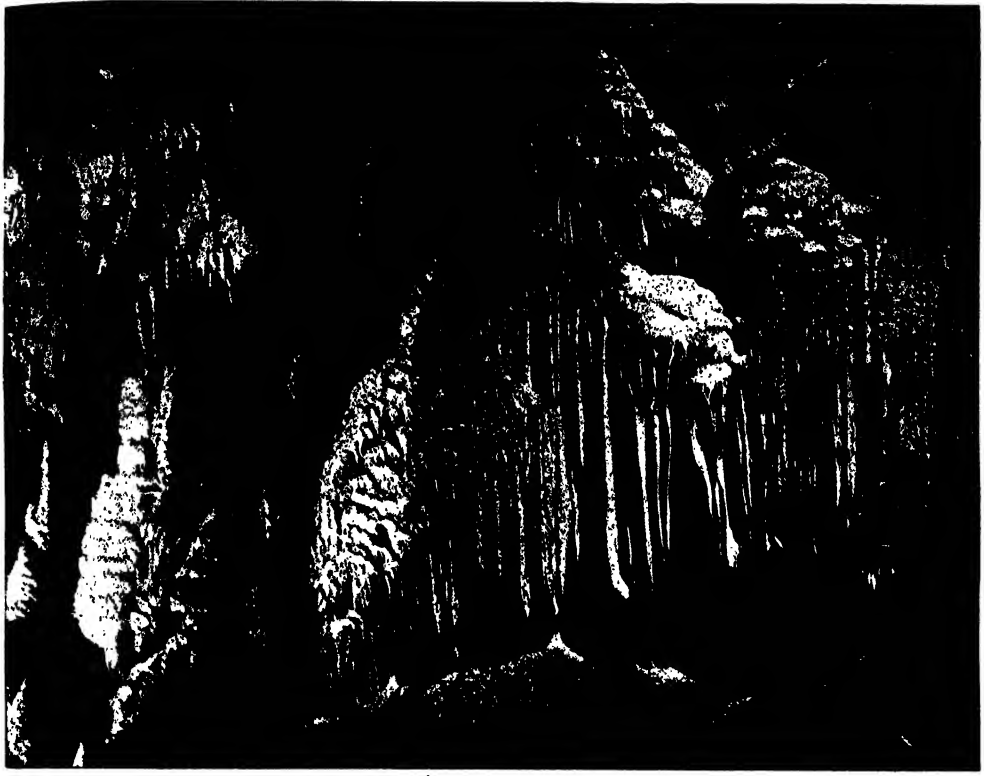
This expansion of water as it nears freezing-point, and at freezing-point, is of great climatic importance. If water, like most substances, continued to contract as it cooled, then the cooler, denser water would continually sink to the bottom, and ice would form on the bottom and not on the top of water. That might seem very good for a while; we might miss our skating, but it would leave the St. Lawrence and the Baltic open to ships all the year round, and it would produce a milder climate round coasts hitherto ice-bound. But it would seem good only for a while. The ice formed at the bottom of the sea and lakes and rivers would not melt. Since water is a very bad conductor of heat, the sun would fail to reach it through the overlying water, and the surface water warmed by the sun would decline to sink and thaw it. It would remain all through the summer and autumn, and next winter a fresh layer of ice would be formed on top of it. This fresh layer, again, would persist through the succeeding summer and autumn, and would be covered by still another layer next winter.

THE SMOKING AND STEAMING ISLAND OF BOGOSLOV IN THE BEHRING SEA

In time, at this rate, all the seas and lakes and rivers within the reach of frost would become solid ice, and all fishes and water-animals would be slain. And now the climate, at first rendered milder, would be rendered much more severe. It would be a case of slush in summer and ice in winter; and though it might be a boon to many to be able to cross the Channel or the Atlantic without fear of mal-de-mer, the boon would be dearly bought, for the Continent of Europe would become an icefield populated chiefly by famine-stricken Polar bears and the centres of civilisation would shift to Timbuctoo and Khartoum.

Water has a remarkable power of dissolving substances. Almost every known substance is to some extent soluble in water and all natural water has solid substances in solution. In so-called salt water the taste of the salts in solution gives evidence of their presence in the water, but even fresh tasteless water has a certain amount of solid substance in solution. The chief mineral substance dissolved in fresh water is carbonate of lime. All water contains a certain small amount of carbon dioxide in solution, absorbed from the air; and water, again, containing carbon dioxide in solution is capable of dissolving carbonate of lime; and since carbonate of lime is almost everywhere present, so all water contains carbonate of lime in solution. Water containing much lime in solution, whether carbonate of lime or sulphate of lime, is known as *hard* water, and in such water some of the lime in solution is liable to be precipitated. So-called petrifying springs are produced in this way. The water issues with a large amount of lime in solution, and when the water evaporates the lime remains behind and forms an incrustation on any objects which are placed in it.

In this way, too, are formed the remarkable bodies known as stalactites and stalagmites. Water laden with lime drips from limestone rock through the roof of a cavern, and, as it drips, leaves a little lime behind. This deposit gradually increases until formations of lime, shaped like icicles, hang from the roof. These are known as stalactites. Again, where the drops fall on the floor of the cavern, they deposit a little carbonate of lime, and to this deposit, drop by drop, a little more lime is constantly added, until in time little conical rods of carbonate of lime stand up from the floor. These are known as stalagmites. Sometimes



LIMESTONE STALACTITES. KING SOLOMON'S TEMPLE, YARRANGOBILLY CAVES, NEW SOUTH WALES

STALAGMITES AND STALACTITES IN COX'S CAVERN, CHEDDAR, SOMERSETSHIRE

stalactites and stalagmites join and form pillars.

River-water contains from two to fifty grains of saline matter per gallon—on an average, about twelve grains. The salts ordinarily contained are as follow.

SALTS OF RIVER-WATER

Calcium carbonate	42·90	Carbonates 57·70
Magnesium carbonate ..	14·80	
Silica	9·90	
Calcium sulphate	4·50	Sulphates 11·40
Sodium sulphate	4·20	
Potassium sulphate	2·70	
Sodium nitrate	3·50	
Sodium chloride	2·20	
Iron oxide and alumina ..	3·60	
Other salts	1·30	
Organic substances	10·40	
Total	100·00	

Sea-water, as is well known, and as its taste indicates, is much richer in salts than fresh water. A gallon of sea-water contains about 2450 grains of saline matter. Its chief saline constituent is not carbonate of lime, as in the case of fresh water, but sodium chloride or common salt—the salt we use at table. Out of the 2450 grains of saline matter contained in a gallon of sea-water, there are over 2000 grains of common salt. The salts of sea-water are as follow.

SALTS OF SEA-WATER

Sodium chloride	77·70	
Magnesium chloride	10·80	
Magnesium sulphate	4·70	Sulphates 10·80
Calcium sulphate	3·60	
Potassium sulphate	2·50	
Calcium and magnesium carbonate	0·30	
Magnesium bromide	0·20	
Other salts	0·20	
Total ..	100·00	

The solids, however, in solution vary in sea-water with the natural history of the water. The following interesting table, showing the salt contents of various seas, has been compiled by Bonney.

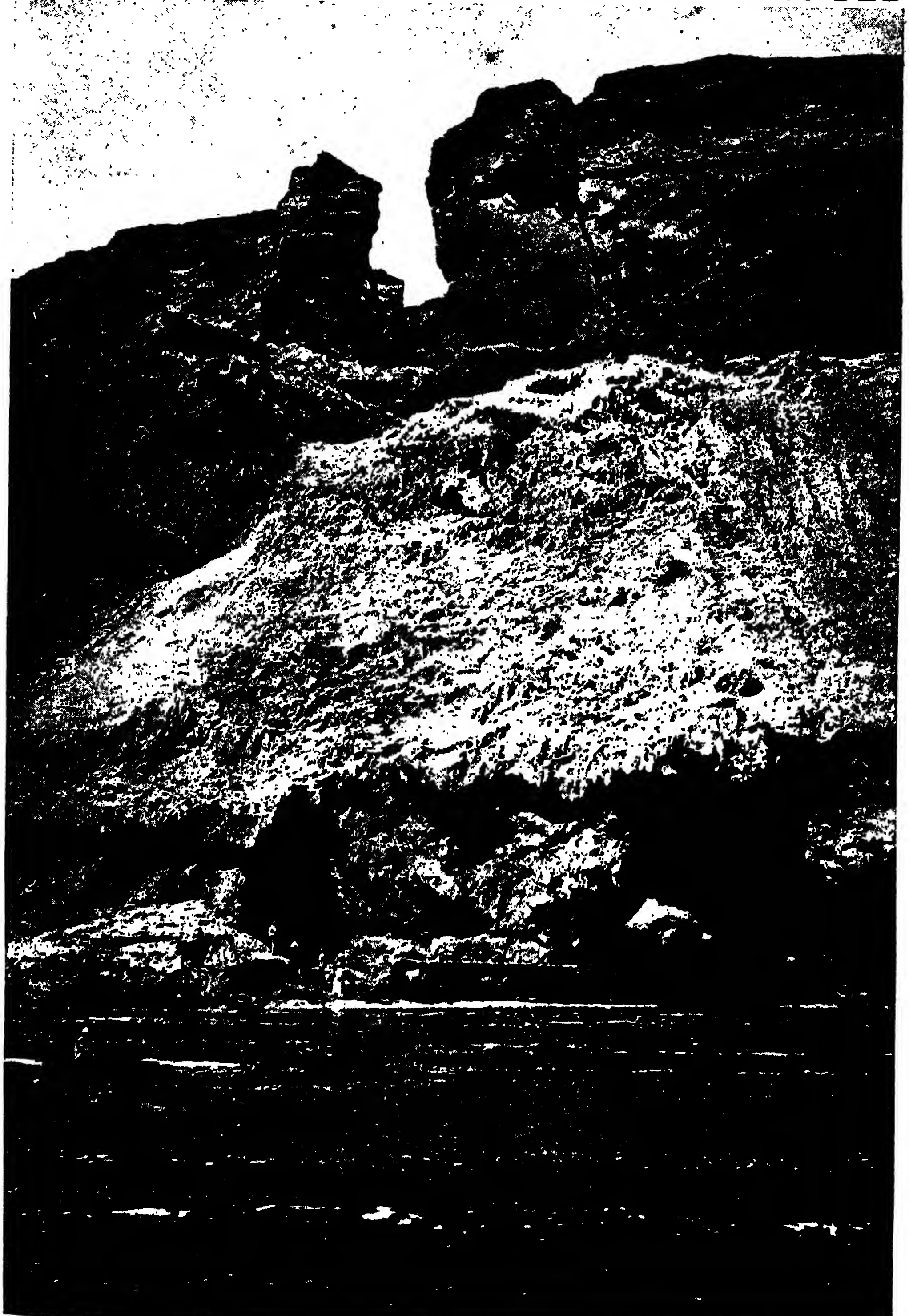
It will be noticed that the salts in solution in the English Channel are not quite the same as the salts in solution in the Mediterranean, and samples collected by the "Challenger" showed variations between 3·301 and 3·737 in the percentage of salt in different parts of the sea. Besides these substances there are many other elements in solution in sea-water, such as iodine, fluorine, phosphorus, silicon, barium, lead, iron, copper, silver, cæsium, and rubidium. Even a trace of gold is found, and more than one wild-cat scheme has been proposed to recover gold from the ocean.

Since the salts in sea-water are derived from the land, it may seem strange that there is only a small quantity of silica and of carbonates; but the reason of this deficiency is that many marine animals and plants subtract the silica and carbonates from the sea-water in order to make themselves skeletons or shells. A single oyster requires all the lime in 27,000 to 76,000 times its weight of sea-water to make its shell. In spring-water there is more than ten times as much silica as in the sea; but at once the little unicellular plants called diatoms begin to use the silica to make their shells, and the store of silica is quickly diminished.

As a rule, the water on the surface of the sea is salter than the water in the depths, and the sea in regions where there is a large rainfall may have its salinity much reduced. The amount of ordinary salt (sodium chloride) and mineral matter in the sea seems inconsiderable when we state it as 3·3 to 3·7 per cent, but the following figures help one to realise how vast the amount really is: In every cubic mile of sea-water there are more than 117,000,000 tons of ordinary salt. If all the mineral matter in the sea were extracted, and spread upon the dry land, it would form a layer more than 400 feet thick. If we could use

—	English Channel	Mediterranean Sea	Black Sea	Caspian Sea (Baku)	Great Salt Lake (Utah)	Dead Sea
Chloride of sodium	2·7059	2·9424	1·4019	8·5267	11·8628	3·6372
Chloride of potassium ..	·0765	·0505	·0189	(trace)	·0862	·8379
Magnesium	·3666	·3219	·1304	·3039	1·4908	15·9774
Lime	—	—	—	—	—	4·7197
Sulphate of magnesia ..	·2295	·2477	·1470	3·2493	—	—
Sulphate of lime	·1406	·1357	·0104	1·0742	·0858	·0889
Sulphate of soda . ..	—	—	—	—	·9321	—
Sulphate of potash ..	—	—	—	—	·5363	—
Carbonate of lime ..	·0033	·0114	·0364	·0554	—	—
Carbonate of magnesia ..	—	—	·0208	—	—	—
Bromide of magnesium ..	·0029	·0556	·0005	—	—	—
Water	96·4747	96·2348	98·2337	86·7905	85·0060	73·9232
	100	100	100	100	100	100

THE SALTY DEPTHS OF AN ANCIENT SEA-BED



A VIEW OF JEBEL USDUM, A MOUNTAIN OF ROCK-SALT, WHICH EXTENDS FOR SIX MILES AT THE SOUTH END OF THE DEAD SEA, AND IS THE DEPOSIT OF AN ANCIENT OCEAN

the same mineral matter to extend the margin of the present continental areas out into the shallower seas, we could add about 20,000,000 square miles to the land surface of the globe; while if we were to heap up all the mineral matter on India, the Himalayas would be buried deep underneath. The common salt in the sea would itself form a continent having a bulk fourteen times the bulk of the present European land above sea-level.

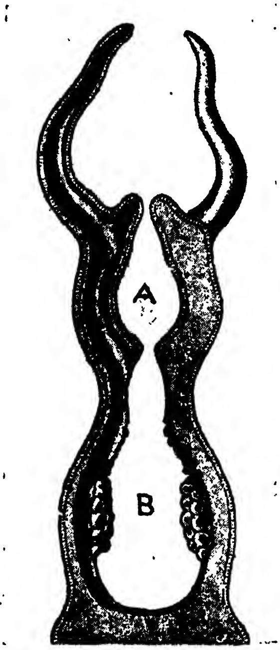
The result of all this mineral matter dissolved in the sea is to alter the thermal properties of sea-water as compared with the thermal properties of fresh water, as we have already described. The capacity for heat of sea-water is rather less, so that it is more easily warmed, and it conducts heat better. This very greatly increases the dynamical force of the sea. Sea-water is also more difficult to freeze than fresh water: its freezing-point is four degrees lower.

Most of the substances in solution in the sea have been added to it by the agency of streams and rivers; it is part of the débris of ancient continents. It has been added year after year, and century after century, and, as we mentioned in an earlier chapter, attempts have been made to estimate the age of the sea by calculating the time required to accumulate its salt.

Probably life began in the sea or in the sea-mud; and recently a French scientist, R. Quinton, has endeavoured to decide the composition and temperature of the sea at the time that life began, by a consideration of the temperature and salt contents of the blood of living animals. The early forms of life that appeared in the sea had, of course, no heart and no blood proper, but the nutrient matter and salts that nourished their living substance were dissolved in the sea in which they floated, and so in a sense the sea-water was their blood.

Following out this idea, it is maintained that the warm salty liquid circulating within the bodies of animals with vascular systems was originally derived from sea-water—that the blood-vessels were, in fact, simply a system of pipes containing sea-water. At first the pipes would be open, as is still the case in the cœlenterates, but after a time, when the sea became too salt to suit the tissues, closed pipes became an advantage, and thus animals obtained a closed vascular system.

Quinton assumes that the hottest blood-temperature of birds represents the temperature of the early sea, and that the percentage of salts in the blood-fluid of birds represents the percentage of salt in the early sea. If this assumption be correct, the temperature of the early sea was 111 degrees Fahrenheit, and it contained only ·7 or ·8 per cent. of salts. But it is likely that life began when the sea was hotter than 111 degrees Fahrenheit, and when it contained less salt; and if the blood of birds be representative of sea-water, it probably represents the state of the sea not at the beginning of life, but at the time when animals with body-cavities came into being—that is to say, the state of the ocean in Cambrian times.



WHERE SEA-WATER IS A VITAL FLUID

The Monoxenia darwini, magnified—a simple polyp, with pharyngeal cavity, A, and digestive cavity, B, into which sea-water freely enters.

Though the salts in the blood occur in less amounts than in the sea, yet the correspondence in their nature and relative proportion is certainly suggestive; and it is interesting to note that during a recent severe epidemic of infantile diarrhœa injections of diluted sea-water (as suggested by Quinton) were found to save many infants' lives. Suggestive, too, is the fact that so many animals have skeletons of lime—an element which is always present in the sea.

Water contains not only solid substances in solution but also gases. Except, indeed, for the gases in the sea, sea-water could not pretend to act as blood. Whatever gases happen to be in contact with water enter into solution, the amount depending on the solubility of the gas on its pressure, and on the temperature of the water. The greater the pressure of the gas, the greater will be the volume absorbed; the higher the temperature of the water. the less will be the volume absorbed. If gas is absorbed under a certain pressure, it will bubble out again when the pressure is reduced, as in the case of aerated waters.

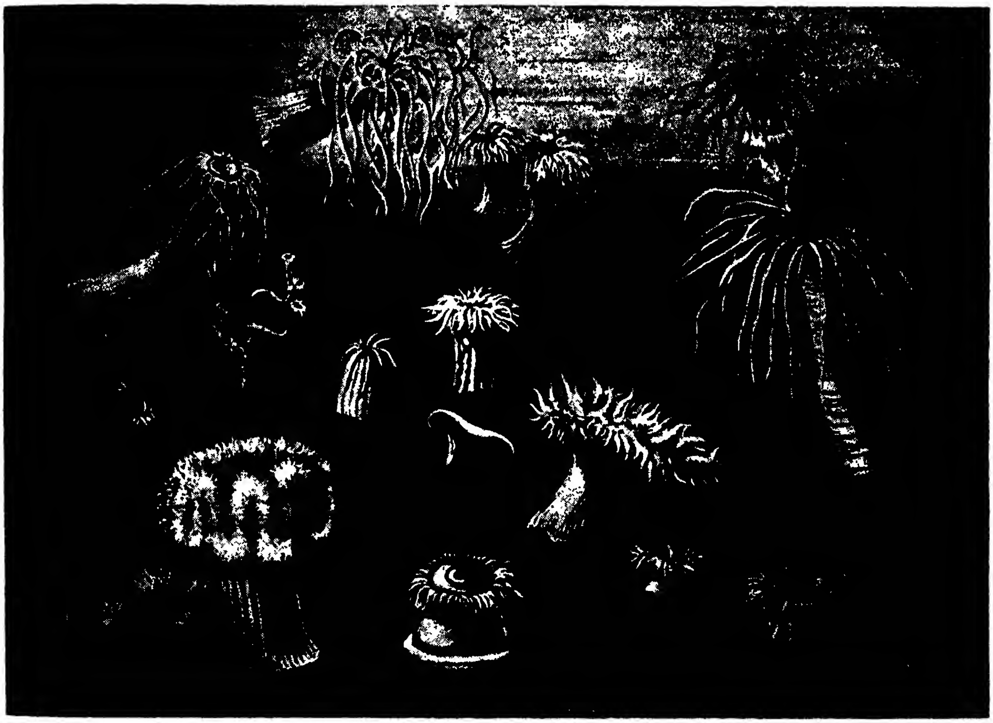
Natural waters are naturally in contact with the gases of the atmosphere, and therefore always have these gases in solution. At a temperature of 0 degree centigrade, and at ordinary atmospheric pressure, 100 volumes of water will dissolve 2 volumes of nitrogen, 4 volumes of oxygen, and 108 volumes of carbon dioxide, provided these gases are equally represented in the atmosphere. but since there is four times as much nitrogen as oxygen and only an infinitesimal amount of carbon dioxide, water contains in solution twice as much nitrogen as oxygen, and a very small quantity of carbon dioxide. The proportion of nitrogen in the water remains the same, however deep we go, but the proportion of oxygen diminishes, since oxygen is consumed in the processes of respiration by marine organisms.

All bodies of water give and take atmospheric gases, as the pressure of these gases and as the temperature of the water rises and falls; and in the case of the sea this give and take performs a very useful office in maintaining the equilibrium of the carbon dioxide in the atmosphere.

Though carbon dioxide occurs in only small quantities in the air, it plays quite an important part in the regulation of the temperature of the earth, and in the due performance of the respiratory functions of animals and of the digestive functions of plants. A little deficiency or excess of carbon dioxide in the air would seriously affect the temperature of the earth, and the vital functions of both animals and plants; and carbon dioxide is produced in such large quantities by animals and volcanoes and coal-fires, and is consumed in such large quantities by plants and rocks, that considerable variation in its total volume might very well take place.

Such variations are, however, automatically checked by the sea; for as the pressure of the carbon dioxide in the air rises, more enters into solution in the sea; and as it falls, some of the carbon dioxide in solution in the sea returns to the air.

How effective this regulation is the following calculation will show: At present there are 3 volumes of carbon dioxide in 10,000 volumes of air. In order to increase the proportion to 4 volumes in 10,000 it would be necessary to more than double the amount originally present, for the sea would absorb much the greater part of the carbon dioxide added.



CŒLENTERATES EXEMPLIFIED BY SEA-ANEMONES, WHICH LACK ALIMENTARY CANALS DISTINCT FROM THE GENERAL CAVITY OF THEIR BODIES

The frog-bit, floating on the surface of pond waters, drops buds that sink to the bottom before winter, as seen in the upper picture, where one bud has sunk, another is sinking, and a third remains attached to the plant. In the lower picture is seen a young plant which has developed from a bud that has risen to the surface in spring; on the left is an undeveloped bud.

These photographs and those on pages 1760 and 1761 are by Mr. J. J. Ward.

A NEW STUDY OF HEREDITY

Hereditary Resemblances and Hereditary Differences: Complementary Aspects of the Same Thing

AN INTRODUCTORY REVIEW OF TERMS

ALL truth is one, no fact contradicts another fact, and the smallest fact in the world may trip up the most imposing philosophy. Science, therefore, which is constantly trying to ascend from details to principles, from the present to the past and future, and "from the static to the dynamic view of things," is also constantly compelled to descend again to facts, to survey them anew, and add to their number without end. At the present time, for instance, a theory of evolution which was accepted for decades is crumpling into fragments before the contents of a pea-pod. We examine the individual peas, knowing their ancestry; and the great theory of evolution by the natural selection of minute random variations goes by the board. That outline illustration of what is to follow will suffice to show that the time has come when we must face the facts, if our study of life and its laws is itself to be vital.

The law of death, as we have seen, is one of the laws of life. The passing of the individual means that the species must be maintained by reproduction. The new individual, as a rule, does not resemble its parent perfectly—compare a human father and his baby boy, or an oak and an acorn—the reason being that the young creature undergoes a period of development before it reaches maturity. In this developmental period all sorts of strange things are apt to happen; above all, in the case of the insects, the young butterfly being *not* a butterfly, but a wingless, creeping caterpillar. All these stages have to be studied and explained, if possible. But, as we study and explain them, we are impressed, above all, with the chief outstanding fact that the offspring resemble their parents at some stage or other, and that resemblance we call heredity.

This resemblance is an essential fact of the life-history of species, for there could be no such thing as a species without it. Equally essential is it for any theory of evolution, or for any theory which denies evolution. If we deny evolution and accept special creation, we still avow a belief in heredity, for we declare that existing forms of life are just as they were made by Deity long ages ago. But we do not therein assert that Deity made the forms now alive. We know those were derived from parents, and those from parents, until the "first parents" made by "special creation" are reached. The identity between existing forms and their "first parents" thus depends upon the most rigid and unreserved belief in hereditary resemblance. No evolutionist, no student of biology, has such an unreserved belief in "heredity," in this sense, as is maintained by the enemies of science who say there is "nothing in heredity," or that "the bubble of heredity has been pricked."

But though the evolutionist cannot be so enthusiastic and indiscriminate a believer in heredity as the believer in special creation unknowingly proclaims himself to be, yet the evolutionist must base all his teaching on the fact of heredity. Certainly he knows that if there were *nothing* but hereditary identity between parents and offspring there could be no evolution, no change of species, no invention of new species—and "special creation" must be true. But while the evolutionist is therefore compelled to assert the fact of hereditary difference between parents and offspring, he also believes in hereditary resemblance, for without it species could not be distinguished and would not exist. If the offspring of human parents were equally likely to be sweet-peas, or "white rats," as Nibs suggests in "Peter Pan," or babies, the world of life would not be the world of life we know, nor any that we can imagine. But

the evolutionist is absolutely dependent upon the details of heredity for any chance of framing a true theory of the *how* of evolution, and that is just the very *crux* of biological controversy at the present time. We know the contents of the pea-pod, of which Darwin died ignorant, though the facts had been laid bare twenty years before.

Such small, immeasurably significant details must be hinted at already, in order to prepare the reader for the long discussion of them which must follow, and in which we shall constantly run the danger of not being able to see the wood for the trees. We are going into the wood in a few paces, and are going to examine the individual trees, for they, after all, make the wood. But now is our chance to see the wood as a whole; and when we emerge and come out into daylight again we shall take another view of it, from the other side, and with "inside knowledge" which will enable us to perceive as well as to see. Let us, then, be quite sure that we see what this "wood" is that we are approaching.

The Whole of Life a Unity of which Individuals are Expressions

It is not a mirage. Only those who have not passed the stage of being able to spell the word say that there is "nothing in heredity." Our illustration of the peas and rats and babies obviously disposes of them. They may reply that that is not what they meant; but if heredity does not mean that the offspring of human parents are human, rather than leguminous or rodent, nothing means anything. Further, if we are sufficiently unconventional to think before we speak, we shall see that, even if the offspring of a human being were sweet-peas, even if one living species could give rise to another, differing perhaps rather less extremely than people and peas, certain hereditary resemblances would remain. Peas must breathe, they are made of cells which contain living protoplasm, they are born and die, they consume food and excrete waste, and so on. Living matter everywhere is living matter, life is life; every living individual is, in origin, a detached portion of one or two previous individuals; and if the nineteenth century proved anything it proved the fundamental identity and continuity of all forms of life. All species, and all individuals of all species, are of common origin, they are members one of another, and they might all be united by physical continuity at this instant, just as the living cells of an individual body are united. To realise this fully is to see the whole of life as a unity, of which individuals are expressions, somewhat as his "living" works are the expressions of the creative life of a man of genius.

The mere discovery of the cell, of which all living bodies whatsoever are made, establishes this truth once and for all, and to see it fully is to understand that what we call heredity is of the very essence of life. It is not an accident, nor anything superposed upon the nature of life, nor one of its evolutionary products.

Our Blood-Cells are to us what we are to the Whole Body of Life

All living bodies are separated parts of one continuously living body of life, born in the remote past, flourishing to-day, destined to live and to develop for ages to come. And the study of heredity is simply the study of the relation between the generations of which this body of life is composed. Just similarly, in the "individual" body of man, we may study the origin and growth and reproduction and death and replacement of, say, red and white blood-cells, which have their generations and their heredity within our bodies, within the course of our lives, and are, in reality, no less individual relatively to us than we are relatively to the whole body of Life, past, present, and to come.

Now, let us come closer to our "wood," and prepare to look at its parts. Already we see something which looks like a serious difficulty, and which has been completely misunderstood until the last decade. For while we can no longer question the fact of heredity, which is as fundamental to life as respiration or nutrition, or more so, we have also to recognise what has already been acknowledged—the fact of difference between parents and offspring. Now, resemblance and difference are opposites. The one is the denial, the negation, the failure of the other; and if hereditary resemblance be a cardinal fact of all Life, what are we to say of "hereditary difference"? Can we even employ such an expression?

Ideas Once Accepted by Science But Now Thrown Over

This is worth spending almost any amount of time upon, for we are just at the beginning of a new epoch in the science of life, the epoch in which, for the first time in the history of knowledge, the relation between hereditary resemblance, often called heredity, and hereditary difference, often called variation, is essentially understood. The understanding of it is contained in Mendel's pea-pod; and the phrase "hereditary difference," which we have purposely

employed, though with a question-mark, exactly expresses our new knowledge. The difference is as much hereditary as the resemblance.

Now, we are here throwing over, once and for all, the ideas which science has accepted and worked upon until our own time; indeed, there are a few survivors of the old school still, wasting fine qualities upon methods and working-principles which the march of knowledge has once for all passed by. We shall not understand what has been achieved unless we realise what those old ideas, still very popular—like so many other dead things—really are.

The Theory of Accident in Heredity called Variation

They sound reasonable, if fairly stated. According to them, heredity is the law that "like begets like." That is as certain as today; and, further, it appeals to our sense of reason. Knowing, as we do, that all individuals are developed from detached portions—detached by budding or splitting, or in the form of seed—of other individuals whom we call their parents, the large general resemblance between offspring and parents is felt to be in the nature of things. "Do men gather grapes of thorns, or figs of thistles?" But though "like begets like," it rarely or never begets exactly like; there are differences, small or great, so minute as to require delicate measurement for their detection, or so huge that we call the surprising offspring a "sport" or a "freak."

These differences, considered as a whole, throughout the world of life, are vastly less numerous and important than the resemblances between parents and offspring. We give them the name of variations; and as they are so much less marked than hereditary resemblance, and seem much less reasonable, we incline to the very excusable view that heredity is the law, and that variation is the "accident," or the exception, to the law. Nothing in this world, so to say, can be perfect; and heredity, though it tries to be perfect, is qualified by little imperfections and accidents which we call variations.

The Supposition that Heredity and Variation are Opposing Forces

This idea can be improved upon, quite easily, we used to suppose. It is not scientific to talk of "accidents," unless we examine the supposed accidents and find that they obey the laws of chance. Let us, then, investigate the resemblances between parents and offspring, on the one hand, and the differences on the other hand. Indeed, why not speak of two opposed forces—the force of heredity and the force of variation? This sounds thoroughly scientific. In the study of physical forces we can measure the onward force of a moving body, and the force which tends to pull it at right angles from its onward path, and then we can achieve what is called the "composition of forces," showing how the planet or the bullet travels in a certain path under the opposing and balancing influence of the two forces which are acting on it. Just so heredity is the force which tends to make an organism go on in the straight line of its species, and variation is the force which acts at a right angle to that; and according to the relative power of the two forces, and the result of their "composition," the new organism will travel along a line which is something between absolute resemblance to, and absolute difference from, the path of the past.

A whole school has been founded on ideas such as these, and has erected wonderful structures, which the growing stream of knowledge, knowing that all such structures are only dams in disguise, has burst into fragments such as are now borne down by it to us, and must be curiously glanced at in a little while.

Heredity and Variation Complementary Aspects of the Same Thing

For, in fact, the great achievement of our age, in this line of knowledge, is to show that "heredity" and "variation" are not opposed "forces," ranged against each other in the field of life. Heredity is not the law, and variation the exception, or the result of some opposed law. In fact, "heredity" and "variation," likeness and difference, are different and complementary aspects of one thing; and if we are to get any further we must cease to think in terms of likeness and difference, and must content ourselves with the admirable definition of heredity, put forward by Professor J. Arthur Thomson a few years ago, that the study of heredity is the study of the organic relation between living generations.

We shall learn, in due course, how this organic relation shows itself, alike in difference and in likeness between the generations, and we shall learn that each of those differences and likenesses has a meaning and a *rationale*, but we must stop thinking in terms of likeness and difference, and trying to arrange all the facts in those categories.

For, if we do, where are we when the offspring differ from the parent but resemble the grand-parent? Is that "variation," or is it "heredity"? We commonly

TRANSFORMATION THROUGH TYPES OF LIFE

The magnified eggs of a butterfly resting on a leaf

Baby caterpillars feeding on the soft parts of leaves

Caterpillars, three weeks old, swarming about nettles

Caterpillars at the fourth week from their birth, when they are quite full grown

A full-grown caterpillar suspending itself in readiness for its change to a chrysalis

At the half-way stage, when moulting the skin

The skin moulted at the end of four minutes

The chrysalis fully formed, the skin having fallen

AS SEEN IN A PAINTED LADY BUTTERFLY

Chrysalids ready for the butter flies' emergence

A butterfly emerging from its burst chrysalid

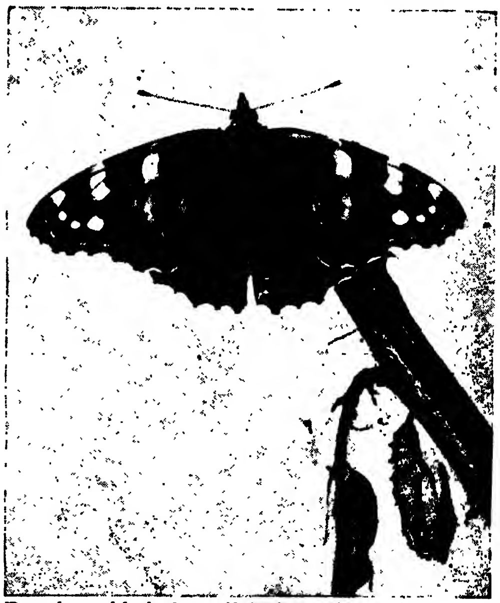
The emerged butterfly crawling on to the stem

The beauty of the insect becoming apparent

The gradual extension and drying of the wet wings

The wings under muscular control at the end of an hour

The butterfly, feeling its strength, quickly travelling to the top of the stem



Opening wide its beautiful wings, the perfect insect is ready to fly

reply that that is heredity "skipping a generation," but, really, our skipping days are over, and we must leave such "explanations" behind us, too. We shall see that, when we start out to observe the organic relation between living generations, not only parents and offspring, but between many successive generations, not only between brothers and sisters, but between cousins even remotely related, then the likenesses and the differences, the "skippings," and "reversions" and "sports," and "atavisms," and all the other things and names that have made such a chaos out of cosmos in our thought hitherto, fall into their places, and serve equally and complementarily to illustrate those real laws of heredity at which, until the Mendelian revelation, no one had even guessed.

Heredity the Organic Relation Between Living Generations

But we have much to learn before we are ready for the invaluable work of that monkish gardener of Brünn. We have made a beginning, however, and that beginning is contained in the clear and simple idea that what we are about to study is not the "law" that like begets like, nor the "law" that like begets not exactly like, but simply *the organic relation between living generations.* If we study that properly, including two generations if they suffice - as they never do—or twenty if we can trace them, and if we make our genealogical tables not only long but also wide—a cardinal necessity in which records of human genealogy deplorably fail the biologist—we shall find that all the various "laws" of heredity and "exceptions" and contradictions take their place in the complete scheme of which we are now becoming possessed.

An Exploded Theory that Excluded God from Part of His Universe

This newly perceived truth, that "heredity" and "variation" are really one, not only places our science on a firm foundation, but it also frees us from a pseudo-religious theory which, after the fashion which all ages illustrate, sought to demonstrate God in one place at the cost of denying Him everywhere else. This theory, which still has its champions, has very ingeniously sought to express evolution in a form compatible with the idea of special creation. No reader of this section has any use for such a theory, for we have already learnt from Bergson and his great predecessors that all evolution is creative. But for those who cannot grasp the idea that God is everywhere or nowhere, there has been invented the theory that heredity (by which is meant identity between parents and offspring) is "natural," and can be expressed in terms of "natural law," but that "variation," the production of the new forms which make for progress, is beyond science to explain, and must be due to the careful interposition of Deity, ever and anon superimposing new elements upon the effects of the natural law of heredity.

It is not easy to express in adequate words the contempt with which such a theory must be dismissed, but we can see how it grew out of the original delusion that "heredity" and "variation" were opposites. The theory has the misfortune of specially crediting Deity with the deliberate causation of degeneracy as well as of progress, for variations are as often downward as upward, or oftener. So that, on this view, Deity is as much concerned to degrade as to create; and it is, in any case, beneath the consideration of grown men and women, or of the smallest child, because it tries to exclude God from the greater part of His own universe.

Differences Between Individuals That Have Nothing to Do with Variation

"Heredity" and "variation," we have said, are really one. Neither can be understood without the other, they are two parts or aspects of the same thing, they depend on the same laws. In a word, the science of life has here reached the same stage of understanding which has been discussed elsewhere in this work for the science of energy. The student of physics knows that rest is a special aspect of motion, and that the laws of motion might just as well be called the laws of rest. We no longer think it "natural" that things should rest, and "supernatural" when they move. Nor again shall men ever be so foolish as to think that heredity and variation are opposites, that hereditary likeness is natural. and that variation—which we now see to be no less hereditary—is due to some interference with the natural order.

That is great gain. The next step is no less important. We have put "heredity" and "variation" together, and have thought of the two terms as simply expressing different aspects of the "organic relation between living generations." And now we must be no less careful to separate, and wholly exclude from any chance of comparison, all those differences between individuals which have nothing to do with "heredity" or "variation," but are due to the different circumstances to which

they have been exposed. An extreme case will serve us best at the moment. A man has two legs, his son has one. This is a difference between parent and offspring in a most notable and important respect. But the son lost his leg in a railway accident; and instantly we recognise that that is really an accident of the individual's personal history, and as such has *nothing to do* with our present subject, which is the "organic relation between living generations"—at least between father and son. Of course, we shall want to ask about the offspring of the mutilated son, but this is clearly a separate question. Now, there are well-known cases where people are *born* with only one leg; and we all see that such a phenomenon comes under our inquiry—for what was the organic relation between parents and offspring if each of them had two legs, and the child only has one?

We have purposely chosen an extreme example, not because we shall ignore the subtler cases, but because a recent fashion, already out of date, has suggested that *all* the characteristics of living creatures are due to heredity, and that there is no distinction between inherent and acquired characters. Our illustration disposes of that absurd view.

Examples of Heredity That are True and That are False

There *is* a distinction, obvious in many cases, such as that we have cited; and we must not deny it there because we cannot define it in other cases. To be born with only one leg, or rather, never, even antenatally, to have had more than one leg, and to have two legs at one stage and one at a later stage, by the direct action of outside circumstances—these are utterly different things. The one-leggedness we call an inherent character in the first instance, and (such are the resources and aptness of our language) we call the loss of the leg in the second case an "acquired character." The phrase, than which the terminology of science contains none more inept or more richly productive of fallacy, is passable in some unimportant instances—also extreme. Thus, darkness of the skin, technically called "melanism," occurs as a phenomenon of heredity in certain cases. There are moths in this country who are going black, from year to year, from generation to generation, and probably birds also. Similarly, we may have to study darkness of skin in a human being. This may be a phenomenon of heredity, as in dark-skinned races. But it may be due to years of exposure to a tropical sun; it may be due to tuberculosis of the adrenal glands, producing Addison's disease and bronzing of the skin; it may be due to extensive tattooing; it may be due to years of dirt and exposure, as in the skin of elderly tramps. The condition of the skin is undoubtedly hereditary in the first case, and an "acquired character" in the others. And what are we to say of it where it is due to Addison's disease, and where the mother had it also, and infected her infant with the microbes of tuberculosis before its birth, as might happen, though with extreme rarity?

The Distinction in Heredity That is Real, Absolute, All-Important

Already the reader will see that this subject is only simple in the eyes of those who have not studied it; and that the first results of study, and more than the first, are to increase confusion in one's mind, instead of lessening it. That cannot be helped, however: we are studying Life, and Life will not be strait-jacketed in phrases or anything else. But if we go slowly, we may go far; and let us lay down the proposition, which greatly helps us, that the relation between the generations is one thing, and the relation of the individual to its surroundings is another. Once we fully grasp that, we can go further, but not till then. The distinction is real, absolute, all-important.

We must recognise it, to whatever extent Life chooses to mingle things so that we lose the thread of them. When we come to trace the relation between the individual and its surroundings, we shall soon find that we cannot follow the threads. We can follow the case of the man whose "acquirement," to use a common abbreviation of "acquired character," is the loss of a leg; or the case of the man whose cutaneous pigmentation is evidently due to tattoo-ink. But what about the loss of the scalp-hair in later life, or in earlier?

Baldness as an Instance of Difficulty in Distinguishing True and Seeming Heredity

It may be due to some parasite, such as favus, which destroys the hair, and that is an "acquired character." It may be due to heredity—the bald young man's ancestors were bald. It may be due to senility—the man's skin is undergoing the natural atrophy of old age, and produces less hair. And even though it be hereditary baldness, the hereditary factor may be a particular susceptibility to the growth of certain microbes which attack the roots of the hair and so destroy them. If those microbes are everywhere, parent and offspring will suffer

alike, and we say, rightly perhaps, that the baldness is hereditary. But if the son excludes these microbes, or goes to some part of the world where they do not occur, he keeps his hair on, though the father lost his; and we incline to say that "there's nothing in heredity." But does that follow?

Plainly, then, we must not mix up different things, producing a simplicity which has no counterpart in Nature, if we are to succeed; and that has been the trouble in this study from the first. Utterly different things have been confounded, the result of numerous factors has been put down to one factor, and all sorts of theories have been invented accordingly which are simply rubbish.

Variation—the Differences which Depend on the Organic Relation Between Parents and Offspring

It needs at least a decade of study to grasp fully the conditions of the problems that are to be solved, but the man in the street will always be ready with an opinion on heredity. He would be silent on the composition of the great nebula in Andromeda, or on the interpretation of the second sound in the cardiac cycle, but he is perfectly clear in his mind as to whether consumption is hereditary or not—a question as to which no expert can yet return an adequate answer.

That is why we must go slowly, and be careful with the use of words. For the moment, let us be content with "acquired character," or "acquirement," to stand for the consequences of the relation between the individual and its surroundings—air, light, food, microbes, books, and everything else—and let us make up our minds that we shall use the word "variation" *solely* to express those differences between parents and offspring which depend upon the organic relation between parents (and remoter ancestors) and their offspring. This is a most important definition.

Heredity and Variation Really Problems of Germ-Cells

Hitherto, and in future, we have used, and will use, the word "variation" only to mean a consequence of the hereditary process, only to mean what depends upon inherent, internal, innate, or inborn differences in the material from which have been developed the individuals whom we are studying. Thus, in a word, heredity and variation are the problems of germ-cells.

The darkness of the skin of the negro depends on something that was in the germ-cells whence his body was formed, not upon the addition of pigment to his skin from outside. The first is a matter of heredity with variation—as when negro parents produce a white child, an albino, that has no pigment at all in its skin. The second is a case of the relation between the individual and the environment, which may plant dirt or ink upon or in the white skin, or may whitewash the black skin.

Unfortunately, biology is only just beginning to be rid of the confused use of the word "variation"; and, as we shall see, the confusion has reappeared where we had thought to be rid of it. Terms which the student will still encounter are "blastogenic variations" and "somatogenic variations," the first being those derived from the germ, and the second those derived from the "soma," or body. It is better to drop these terms entirely, for experience has shown the confusion which follows them. Only that which is of germinal origin is to be called a variation.

That is a most satisfactory stage to have reached, for it clears up the kind of paradoxical atmosphere that seems to hang over the assertion that "heredity" and "variation," likeness to parents and unlikeness to parents, are both really the same thing, and are both hereditary. Of course they are, we now see, for they both spring from the character and contents of the germ-cells, and the germ-cells *are* the hereditary material—they are the inheritance, and they form the heir.

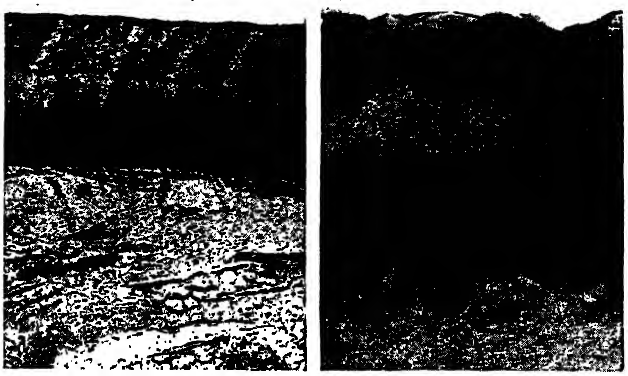
The Many Uses of the Confusing Word "Congenital"

Whatever comes out of them, whether likeness to parents or unlikeness to parents, is demonstrably, necessarily, and equally hereditary; and the apparent contradiction of asserting that heredity and variation are different aspects of one thing is seen to be in the nature of the case, and not a contradiction at all. Similarly, one may inherit assets or liabilities; they are exceedingly different, but they are both equally inherited. When we come to study Mendelism, and the "presence or absence theory" of Professor Bateson, we shall see that the likeness or difference between offspring and parent may just exactly depend upon the presence or absence of certain "factors," as the Mendelians call them, in either of the two germ-cells which are the offspring's heritage, and are, indeed, the inheritor.

In proceeding with this preliminary study of the ideas and vocabulary of our subject, we now light upon the word "congenital." The term will long be employed in medical and other discussions of heredity, but the biologist has ceased to use it. Medical men

habitually use the word in from four to six distinct senses. They speak, for instance, of a "congenital" fracture inflicted at birth. They speak of "congenital" club-foot, meaning thereby a deformity produced by some accident before birth. And they also use the word "congenital" to mean innate, inborn, or germinal, as in the term "congenital stenosis of the pylorus," where the narrowness of the pyloric end of the stomach is an inborn or germinal variation.

Here is wild confusion enough, in all conscience. But doctors also speak of "congenital heart disease," meaning with perfect indifference either deformities of the heart that are due to innate causes, or deformities due to inflammation caused by the poison of rheumatic fever circulating in the blood of the mother. They also speak of congenital plumbism, where the child is born suffering from lead poisoning; and of "congenital syphilis" or "hereditary syphilis" — of all possible confusions — where the child has been infected with a certain minute parasite of disease; and of "congenital blindness," which is due to an infection acquired at birth.



THE SKIN OF THE NEGRO AND WHITE COMPARED

The darkness of a negro's skin, shown on the left, is caused by pigment in the lower layers and not on the surface, where the colour resembles that of the white. The negro's skin is an example of heredity; and melanism in whites, due to years of exposure to a tropical sun, or to disease, is an example of an acquired character.

There is no better instance of the danger of words, against which Bacon warned us all at the dawn of modern science. As things stand, the word is much worse than useless, and nothing can be done but to leave it out of our serious discussions altogether. For the foregoing is only half of the objection to it. Whenever the word "congenital" is used, it leads people to suppose that *only* what appears at birth is inborn. And then we suppose that what appears after birth is acquired. As the young creature grows, after birth, new characters appear, and we are tempted to say "it acquires new characters." But they may be inborn. A man's beard, which does not appear for many years after birth, is yet assuredly inborn or germinal; whereas a deformity present at birth may be due to an accident, and is yet called congenital. Science can make no progress in such a welter of thoughtlessness; and it is time we remembered the caustic remark of Hobbes: "For words are wise men's counters, they do but reckon by them; but they are the money of fools." "Congenital" has too long been the money of the people Hobbes mentions, and it is of no use, even as a counter, to the wise, for how can you count with what never has the same value twice? But how much print and talk and temper would have been saved in the long and acrimonious controversy over heredity if men had been wise enough to use unmistakable and unchangeable counters from the first?

So much for the most treacherous word of all; we shall not mention it again. But a pair of words remain which must also be noted. They are "reversion" and "atavism." When a man takes after his grandfather, we call it a case of "atavism"—heredity "has skipped a generation." Or if the resemblance is to a much remoter ancestor, we speak of it as a case of "reversion" — as when modern pigeons produce a "blue-rock," or a child has a feeble intelligence and is supposed to be a "throw-back" in the direction of some ape-ancestor. These words and notions are really obsolete. They sound well, but they do not correspond to what really happens, as we shall see. If we are to get into the heart of this most difficult subject, which underlies all the problems of the living world, we must make a clean sweep of most of the old terms and most of our preconceptions. That is what the present chapter has sought to do.

And now if only we remember to forget what we thought we knew, but what was not knowledge, we may proceed to make a beginning with the real knowledge of what we shall learn to call *genetics*—the study of genesis, "the organic relation between living generations."

A TREE AS WATER-FACTORY & FILTER

THE TRAVELLER'S TREE IN JAVA POURING FORTH, THROUGH AN INCISION IN THE STEM, A JET OF PURE WATER WHICH IT HAS ITSELF PRODUCED

THE ENERGY OF PLANTS

The Wonderful Sun-Drawn Rush of Life Through all the Earth's Eager and Irresistible Growths

PLANT-PRODUCTS THAT BEGGAR GOLD

EVERYONE who has eyes to see has noticed the surprising energy of plants small and great. They exert this energy in a variety of ways, sometimes by direct mechanical and material effort; sometimes by subtle forms of leverage and the use of the wedge; sometimes by rather mysterious processes of attraction and repulsion; sometimes by chemical change.

Instances of all these are common; indeed, it may be said universal, but some, at any rate, may perhaps be best observed in their rarer and more peculiar forms. An example that has much interested travellers may be seen in many parts of Java, where a plant is used for practical purposes as a fountain. The stem is cut at several feet off the ground, and from the severed pipes pours almost continuously, during the growing period, a jet of the purest water, refined and sweetened in the laboratory of the stem.

You may see such a plant-fountain in tiny form in many English plants, a blade of corn, for example, but the energy is only enough to raise occasional drops of water. It is still rather a puzzle to botanists how this force is exerted, for the force is enormous. A watery fluid has to be pumped to the top of the highest tree, it may be sixty feet or more high, against the natural and universal force of gravity. This could not be done by what is known as "capillary attraction"—that is, the force by which water is attracted from one atom to the next, irrespective of up and down, as when blotting-paper or a lump of sugar is dipped into a fluid. But attraction of this sort could not account for the upward flow of the sap except in a very minor degree, nor could it exert the energy that is found.

The reason may lie partly in the "turgidity" of the successive cells out of which a plant is formed. The cells, we know, have a capacity—in itself rather inexplicable—of growing turgid—that is, of swelling and exerting pressure all round. Such pressure may be very violent, and, by quite understandable mechanical devices or processes of growth, only find its way upwards, not downwards, as the exploded powder in the cartridge set in a raised barrel.

But this theory is little more than finding a new name for an inexplicable thing. It rather suggests the presence of an undiscovered cause than explains with sufficient precision a probable cause. A more certain force is the familiar behaviour of liquids, known in science as osmosis, by which liquids in neighbour cells have a tendency to pass one into the other, the thinner liquid passing the more rapidly of the two through the intervening membrane. But not all these suggestions quite account for the attracting power of the pump which carries sap at an astounding rate up to the remotest leaves in a great tree, and does not fail them even when water is evaporating from them at a great pace.

A number of experiments have been made to test this force. One of the earliest was with a vine. The stem was cut in the spring, when the vital force began to become active. On the cut stem a tube was fitted in a particular manner, and mercury introduced at the end. The force of the rising sap astonished even the experimenter, for it was found to equal the pressure of an atmosphere and a half. A simpler experiment is to tie a bladder tightly over the cut stump. If the tree is at all vigorous the pressure of the sap will be enough to burst the bladder.

How many tons of water are thus raised even within the confines of a small garden becomes a sum of vast magnitude. This activity is a part of the energy of life, that inexplicable and final wonder; but you

may see the presence of an active force even when a part of the plant—especially, of course, the seed or its equivalent—is severed from the parent.

Some curious experiments have been made recently in London. For example, a potato tuber is pricked with a needle, which, of course, breaks and damages the cells through which it passes. As soon as the needle is withdrawn, signs of activity become apparent. The potato is setting to work to heal its wound, and this effort is associated with an escape of electrical energy which can actually be observed on an apparatus in the laboratory. Similar production of electricity has been recorded on delicate instruments attached to seeds, especially eating-peas at the time of germination. A lady worker in London had exceptional success in detecting this electrical energy. Very little is yet known about the operation or origin of this mysterious power. The more electricity is used by man, the less in some ways its real meaning in the scheme of things seems to be understood. But the force is there in the growing seed silently pushing to the greater life as surely as in the heaven-wide lightning whose report crashes noisily from horizon to horizon. It is a suggestive thought that the wheatfields in autumn or the garden in spring are quivering with the emergence of an energy which in some unseen way seems to be involved in the very mystery of life itself.

The Astounding Force Working Irresistibly Through Soft and Delicate Plants

It requires no subtle or delicate experiment to test the astounding force which plants exert in the course of growth. The soft and delicate rootlets make their way as surely as if they had intellect and instruments to the parts of the soil where moisture is to be found, even if the intervening space seems to be of material hard enough and rough enough, you would think, to crush and kill them. As the roots swell they will force up tons of earth or rock. The stem, as it thrusts upwards, will shatter stones to fragments—as in the wonderful case of the tombstone at Tewin, in Hertfordshire; will wrench thick iron into fantastic shapes, and finally tower upwards according to the irresistible law of its being.

This power is hardly less conspicuous in the tender plants than in the stouter trees. Watch the slender spikes of crocus, daffodil, or snowdrop pushing up to

"Hail fair summer with their lifted spear."

They take little heed of clod or stone, but rise straight and true, the inward force too strong for the outward resistance, to meet the longer days and beckoning sun. These things are worthy of wonder and admiration, yet the supreme wonder is the purely physiological and chemical energy in plants.

On the transformations which go on within plants the whole world entirely depends. Without the laboratory work which plants perpetually practise all life would at once cease. Earth, air, light, and water are useless for providing the sustenance of life to animals, but they are not useless to plants, which alone have the secret of transforming them into the substances of which the plants themselves consist, and upon which men and other live things feed. It is for this reason that more and more each generation botany is coming to be regarded as the mother of sciences.

The Analysis of Dead Things Deserted for a Study of the Secrets of Life

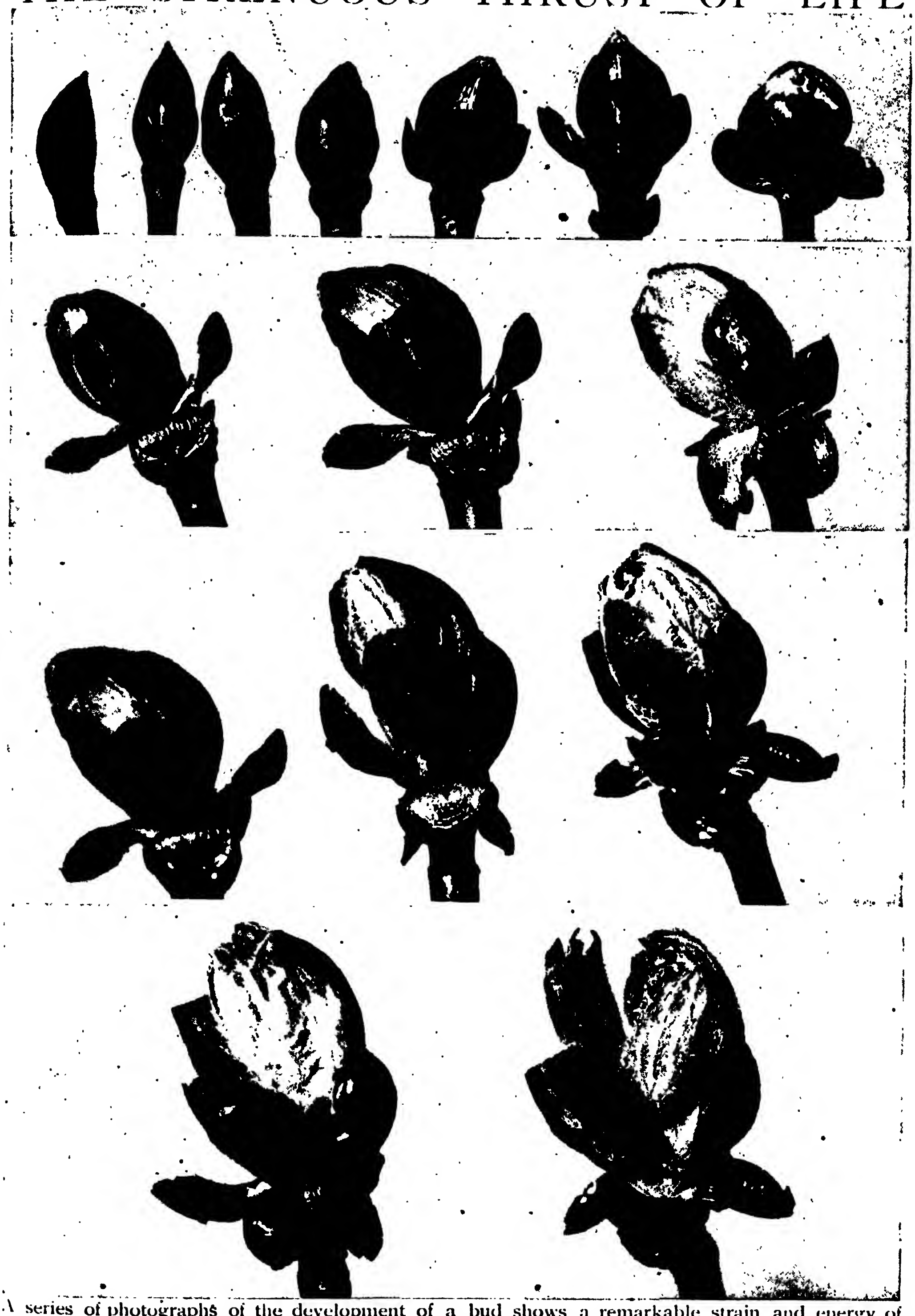
The chemists begin to spend less time proportionately on analysing and splitting up into their parts the dead things which lie about the world. Less and less do they argue in the old way that because such and such things are formed in such and such a combination, therefore certain other things must happen. It is seen that to this kind of knowledge there is an end, and that out of it, immeasurably valuable though it is and will be, can never issue the real secrets of life. Therefore, the men of science are advancing to the consideration of chemical changes in their relation to living things. They do not leave out the living spark, but examine and analyse under conditions of life.

In the growth of a plant is the ultimate secret. Tennyson spoke more prophetically than people of even that date understood when he made his quaint and much-quoted verse about the "flower in the crannied wall." If this could be understood, "root and all, branch and all," we should at least begin to understand what man is in a scientific as well as a mystic sense.

How Every Eatable Thing is Made by Plants from Invisible Materials

A very great deal is known about the chemical power of plants. The first thing to grasp is that every simple thing we eat—sweet, or sour, or bitter—is manufactured by plants out of substances which, like the chameleon, "feed on light and air," and on earth. There is no food whatever that is not, in the first instance, so made; so the learning about this manufactory is one of the most elemental of all studies. The

THE STRENUOUS THRUST OF LIFE



A series of photographs of the development of a bud shows a remarkable strain and energy of purpose. The photographs on this page, by Mr. J. J. Ward, represent a horse-chestnut as it unfolds during the month of March.

manufacture in the bodies of animals of one substance into another is secondary and much less wonderful. Meat and milk are much less remote from the grass out of which they are made than grass is remote from the sunlight it is said to "bottle."

The beginning of the miracle may be said to be the first tinge of green in the seed-leaf. This green colour is the outward and visible sign that these qualities in Nature which lie beyond our use are being turned into the stuff of life. Without the aid of what may be called this chemical miracle we should all be like the parched Ancient Mariner in the poem, surrounded by "water, water everywhere, but not a drop to drink." We should be in a waste of earth and air with not an atom to eat. Why or from what inward impetus the change began we do not—perhaps we may not—know, but nothing in the march of human intellect is more noteworthy than the precise and particular knowledge of the course of these changes. How, is a question that men of science can answer with a thoroughness that the men even of a hundred years ago would have held almost miraculous. Why, and whence, and whither, and wherefore, are some of the questions which overstep the kingdom of science and the wit of man.

How Plants Manufacture the Food Supply of all the World

We must therefore now only consider the "how"; and the story is not less full of wonder and interest because it must be told to some degree in words which do not carry an air of interest on their face. If there is one thing in the world of supreme importance among chemical substances, it is carbon; and it is in the production or manufacture of carbon, if the wording be allowed, that the supreme utility of plants consists. They are the only converters of the element that is in one sense at the basis of all the food-supply of the world.

This conversion into a substance fit for the food of animals goes on in the various processes of growth. Plants are energetic, very much in the sense that animals are energetic, except that they do not, as a rule, move about. There are examples of moving plants and bits of plants, about which Mr. Francis Darwin has, in the twentieth century, made some interesting experiments. But these are exceptions. For the most part the activity of plants is within themselves. Like animals they breathe in and breathe out. They have mouths. They eat and digest, but they eat not compound and solid substances, but largely the elements out of which air and water are composed, in addition, of course to a quantity of mineral substances from the soil, changing each and all of these into food for animals.

It is not necessary now to describe all these processes of growth. You can see them all in the most simple experiments, such as any one may make in any house. For example, if you put a plant into coloured water, you may watch the water, still retaining its colour, running up the little roots. You know, from your eyes, that it is taken in, but you have to infer the further fact that the hydrogen and oxygen out of which it is composed are separated and used to make the substance of the plant.

The Breathing of Plants as Men Breathe and Also by Exhaling Pure Oxygen

Again, you may easily see a plant breathe out. Take any evergreen leaves—laurel leaves are the best—and place them in water in a strong light. Within a short time numerous little air-bubbles will appear. They are the breath of the plant, composed, it is likely, of pure oxygen, that wonderful gas without which no man can live even for a few minutes. "The life-giving gas" is its name in some languages. Now, human beings, when they breathe, use the oxygen, and breathe out that part of the air which is poisonous to them, namely, carbon dioxide. They never breathe out pure oxygen, as do the laurel leaves.

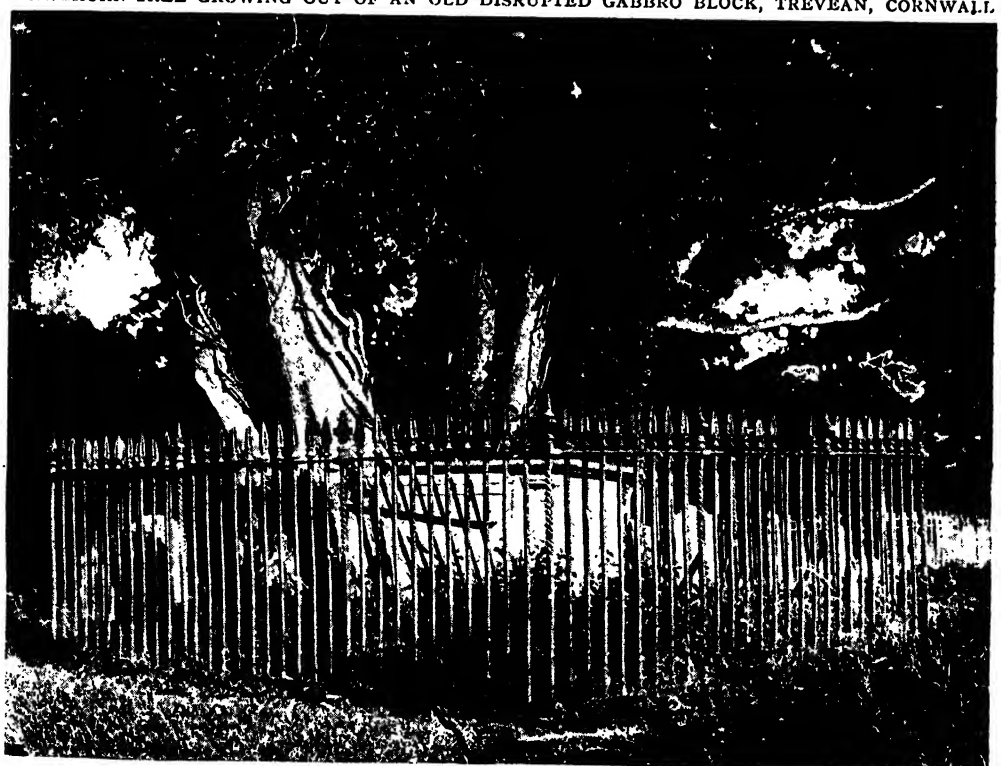
It is, however, necessary to remember that plants breathe in exactly the same way as men, as well as in this way which is peculiar to themselves. But the manufacturing process, about which we are now concerned, is chiefly associated with this habit of breathing out oxygen. What a plant can do, and no other natural agency can do, is to take in this more or less poisonous gas, carbon dioxide, which is found in most air, to separate the carbon, and employ it for the building up of their own tissue.

A Process by which, under the Sun, Plants Manufacture Carbon

But this act of manufacture on which the world depends can only be done—except in rare cases, which are not properly exceptions—under the aid of the sun.

When the light of the sun, whether direct or indirect, falls on a plant, there is formed a green substance, named by botanists chlorophyll, a word simply meaning in the original Greek "green leaf." This green and slightly sticky substance, which in spring

HAWTHORN-TREE GROWING OUT OF AN OLD DISRUPTED GABBRO BLOCK, TREVEAN, CORNWALL



THE TOMB AT TEWIN, HERTS, THROUGH WHICH ASH AND SYCAMORE HAVE BURST THEIR WAY

paints our world with the colour of health, is to plants what blood is to animals. It is, indeed, more. Whenever this is present, and only when it is present, is the manufacture of carbon active. The chlorophyll is the fire which runs the factory; or we may say, perhaps more accurately, that the sun is the furnace and the chlorophyll the electricity, which the furnace creates for carrying out the work in hand and moving the machinery.

The Tree in Summer a Factory Working Full Time

In a very short, rough summary, the whole process may be expressed thus: The roots of plants take up a number of minerals from the earth, and a supply of oxygen and hydrogen from the water, as well as a small amount of carbon dioxide, which is soluble in water. The leaves perform the work of breathing in carbon dioxide, and within themselves, helped by the sun through the agency of this mysterious chlorophyll, they breathe away the oxygen, separating it off from the carbon, which is passed down the plant, providing the chief material for the food of the world.

All this could scarcely be done unless the leaves or furnaces possessed a host of special qualities over and above this secret of changing and breaking up minerals. They have also many additional tasks, which cannot be described here and now. They must be thin and large and possessed of the power of reaching to the sunlight. Even in an elm-tree, bearing thousands upon thousands of leaves arranged apparently in a haphazard mass, you will find that an enormous proportion are cunningly arranged so that they avoid shade and seek light. In some trees you will find the leaves of a shoot making a mosaic pattern so perfect that not a hundredth part of the leaves is obscured, though they are nearly touching one another. When you consider the vigour of a great tree in early summer, when each leaf of unnumbered thousands is at the work of transmuting all that it absorbs into a substance more precious than gold, you will see the tree under a new light, as a factory working at full time with an energy scarcely to be calculated in figures.

The Making of Starch and Sugar in Plants and the Storing of Energy

A great part of all this energy goes in several great divisions of plants into the work of concentrating the precious materials —the hydrogen and oxygen and nitrogen and carbon—into material needed either for the next generation of the plant (that is, in the seed), or into food for next season's growth, as in the potato or carrot. In wheat, almost all the grain consists of starch, one of the most valuable of human foods. When the outer husks are taken off the grain, and the almost invisible germ of the new plant is removed, almost all the rest is starch. This is stolen by man from the would-be plant of next year to provide what is often called the "staff of life."

The factory also turns out sugar at a good rate. Sugar is found in many parts of different plants—from raisins, for example, and from manna, but the most important supply is, for men, in beetroot and in sugar-cane. In the East Indies, no less than 17 per cent. of the sugar-cane is pure sugar, and of this sugar 42 per cent. consists of carbon. In the sugar-beet (which has a bulbous root almost exactly resembling the parsnip, not the beetroot) the sugar is meant to supply food and vigour for the plant in its second year. According to the proper nurture of the plant the energy goes in the first year to the storing of food which will successfully provide it with vigour and ability for seed-bearing in the next year.

The Change of the Plant into Heat by Burning a Proof of the Storage of Energy

Different plants, like different factories, turn out different products. The nut is largely composed of fats and oils, which also consist of the element of carbon.

How much energy is stored up in a Brazil nut, for example, may be seen by changing the oil into heat. Cut a part of the kernel into a pyramidal shape with a pointed peak, and put a match to it. You will find it burn for a brief while almost as clearly as a good candle. The heat or light is no more than another form of the energy of the oil which springs from the energy of the sun working on the elements of which our world is composed.

The immediate object—if the word may be used—of each plant is to provide for its own well being, but the world is made on such a beneficent plan that what is best for the plant is also perfectly adapted to the use of the animal life in the world.

Watching the splendid energy of growth, we feel that every wish of man is satisfied. Spring pleases every faculty, satisfying our sense of beauty and of wonder, at the same time that it provides all that is necessary to feed us and to clothe us, and to supply our luxuries and increasing needs. The fluid that pours out of an indiarubber plant is a fountain of energy comparable with the plant-fountain that was described above.

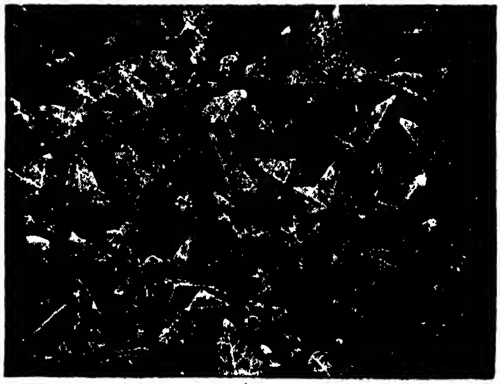
and it makes possible some of the greatest material advances of the age.

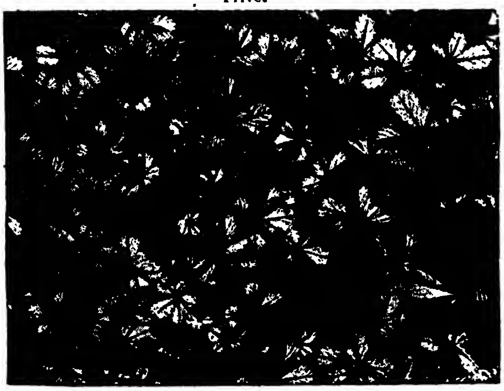
One cannot live a day, or notice the common things of life, without coming back to this vital energy of plants and the manufacturing energy of the tender leaves. The coal we burn is only giving back, in the energy of heat, the same energy by help of which sun and leaf and root and stem fashioned out of iron-hard minerals and intangible, invisible gases this hard, unpromising form of carbon on which so much of the material work of man depends.

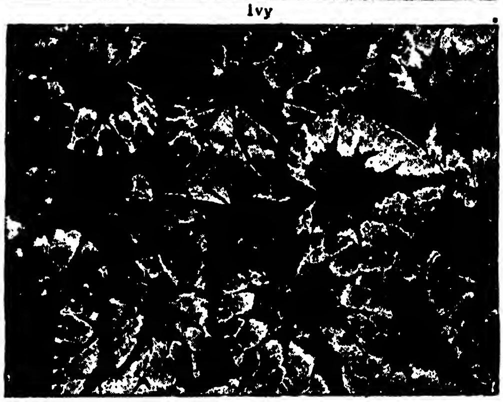
Plants may supply a fountain of water, or of gum, or of rubber. They may also supply a furnace, not in the indirect way of coal, but by their direct activity. At a certain period in their life a number of plants generate a heat which may seem incredible. We have seen elsewhere that the inside of the bell of a snowdrop flower is often two degrees warmer than the air about it, but accounts are given by writers on the botany of tropical and sub-tropical places which describe how, in certain plants, notably in Mauritius, such chemical energy is exerted that parts of the plant are raised 17 degrees and more above that of the surrounding air; and there is no more telling evidence of energy than emergence of heat.

As we look over the whole field of Nature we find signs of forces that baffle and astonish us. A tree can pump up plentiful water to the height of over sixty feet, which is twice as high as any vacuum pump can raise it. We find starch and sugar and a host of valuable substances formed out of hard and invisible and unusable materials. We find the production of electricity—that strange and strong expression of the most mysterious of forces. We find everywhere the exercise of a power of growth by which apparently tender things are able to thrust aside clods, and remove stones, and even shatter solid rocks. Nor must we omit the energy of those bacteria—which are rather botanical than animal—which in and under the soil drive a factory as powerful as that of the leaves, with the same end in view—the alteration of crude and (in the crude state) useless substances for the service first of the plant and afterwards of all creation.


Privet

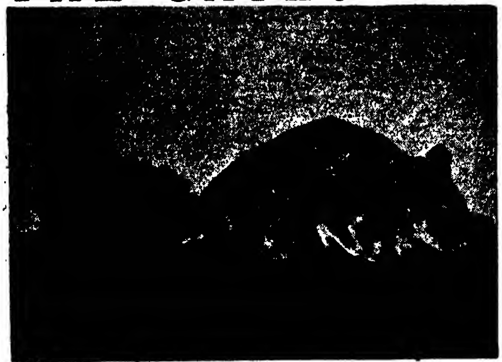

Ivy


Creeping cinquefoil


Sowbread

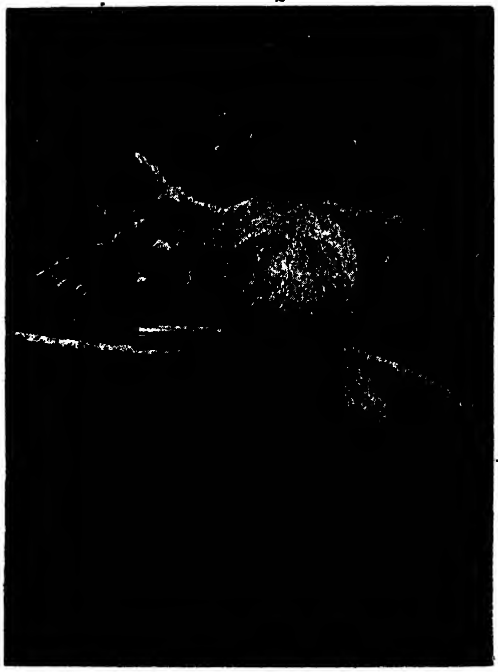
THE GREED OF PLANTS FOR SUNLIGHT—FOUR EXAMPLES OF LEAF MOSAIC

THE GAYEST OF THE RODENTS

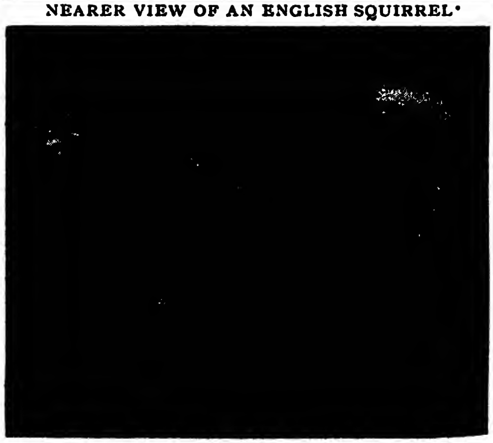

AN AMERICAN FLYING SQUIRREL


AN ENGLISH SQUIRREL


A LARGE RED FLYING SQUIRREL


NEARER VIEW OF AN ENGLISH SQUIRREL


THE AMERICAN GREY SQUIRREL


JAPANESE FLYING SQUIRREL WITH PARACHUTE

The photographs on these pages are by Douglas English, L. Medland, W. P. Dando, and Chas. Reid.

THE GNAWING ANIMALS

A Vast Order of Prolific Mammals with which Man is Compelled to be Constantly at War

THE PROBLEM OF ANIMAL DESTRUCTION

THE rodents, or gnawing animals, bring us to the most widely distributed of all the mammalian orders. Embracing close upon two thousand species, many of them almost incredibly prolific, the rodents constitute, by sheer weight of numbers, man's most formidable mammalian competitors. A glance at the life of the rodent world fills with despair those who would hope for a fulfilment of the pledge that the lion shall lie down with the lamb. Only by the constant making of war by carnivorous birds and animals upon the rodents, by the unwaning stress of the struggle for existence in which the weakest and less adaptive are mercilessly obliterated, only through the recurrence of those silent, far-reaching tragedies in Nature whereby these animals are swept in unnumbered millions to swift destruction, can man maintain his place in life. The inexorable cruelty of Nature's laws is, in the last resort, man's paramount defence against these creatures.

It is a strange and grim cycle of alternating prosperity and adversity that maintains the balance of the rodent world. We have among these animals highly organised creatures, far advanced in the scale of evolution—a tiny harvest-mouse is infinitely ahead of the giant kangaroo in this scale—multiplying in favourable seasons like the grain of the skilful husbandman. That increase brings inevitable disaster. Starvation and disease impel a vast migration—to certain death. If the course were varied, if this cruel annihilation did not follow, the rodents would overrun the earth, and leave man starving in a barren land.

Consider for a moment the rabbit, the chief pest of Australasia, owing to the introduction of a few couples by one of the early colonists. It has been shown that a pair of Australian rabbits will produce six litters a year, the litter averaging five individuals. As the offspring themselves are sexually mature at the end of six months, this one pair, if none died, might be responsible in five years for a progeny of over 20 million rabbits. The ratio of increase with the rat and the mouse is even more alarming. With all our viruses, our traps, our dogs and cats, it is computed that rats cost Great Britain alone some fifteen millions a year, a sum sufficient to carry out comprehensive schemes of social reform. The animal has not a sane apologist. It is useless where sanitary science in even its most primitive form is practised; it is a robber; it is a conveyer of dread disease; it flourishes in spite of man, to his great detriment.

The immense area over which the rodents are spread is a convincing answer to those who still affect to believe that each species originated in the surroundings best fitted for its habitation. Rodents are like weeds: they display extraordinary fertility and persistence in a new land. That is not peculiar to these animals, of course. The red deer of New Zealand have far outgrown the size of the Scottish stock whence they were derived; the domesticated reindeer imported into Labrador rival in size the giant wild reindeer of Siberia; the foxes, carried in an evil hour by a Cumbrian sportsman, for the sake of a hunt or two, to Australia, have become infinitely larger and more powerful and destructive than the old English stock of which they are the descendants. But the multiplication of rodents in new areas eclipses all other examples of the kind.

The gnawing mammals are an instance of Nature's ability to ring the changes upon one design. Certain peculiarities of the rodent's molar teeth recall the dentition of the extinct mastodon, while a peculiarity of the guinea-pig has its parallel in the molar tooth of the modern elephant. The incisors

of the rodent are suggested by those of the curious aye-aye, which belongs to the lemur group. These incisors are the paramount feature of interest in the dental equipment of the rodent. With these front teeth it gnaws. It has two in the lower jaw and two in the upper, except in the case of the hare and rabbit, in the upper jaw of which four incisors are present.

A rodent's incisor is one of the finest tools in Nature. It is a natural chisel, provided on the outer surface with a hard enamel, and on the inner surface with bone which is comparatively soft. As the tooth is used, the inner, softer side readily wears away, always maintaining the sharp edge which the enamel imparts, so exposing a fine cutting surface. The whole tooth grows continuously throughout the animal's life, at a rate commensurate with use, so the rodent, be it beaver or porcupine, hare or mouse, has ever a perfect equipment of tools in its mouth. The chisel is modelled, probably unconsciously, upon the rodent's tooth, with soft iron on one side and hard steel on the other. The axe is a double chisel, with steel in the middle of the blade and two sections of softer metal, one on each side.

THE KANGAROO OF THE RODENTS: AN ARABIAN JERBOA

Another peculiarity of the rodent mouth is that it is departmentalised. The fur of the face is continued into the mouth, which it divides into two distinct sections. The purpose of this is to guard the animal from the danger of getting into its throat any foreign substance which it may be gnawing. The entire mouth of the rodent, both as to this particular and as to the teeth and the specialised shape of the jaw, which admits of the peculiar movement necessary to the mastication of the animal's food, is a beautiful example of adaptation. The majority of rodents have five toes to each foot; and though there is not a thumb or an opposable great toe in the whole order, the extreme mobility of the forepaws of the beaver, the rat, mouse, squirrel, and other animals, strikingly suggests that a rat or a beaver with thumbs must have gone very far in the mammalian scale.

We shall have to content ourselves in this chapter with glances at some of the more notable rodents. We shall reach the rats, mice, voles, and porcupines in later chapters, while important members of the order have been discussed in the preceding paper beginning on page 1653. We have to note by way of further preface that homes are fashioned by these animals in pretty well every available medium. They burrow, they build, they nest, they swim, they even "fly." We find the flying animals among the squirrels, which constitute the first family of the order.

The flying-squirrels are more common than is generally supposed. They occur in practically all the Oriental countries, in North America, in North-Eastern Europe and Asia, in Siberia, in India, in the Malayan countries, and so forth. Of course, the so-called flying is only parachuting, performed by means of a fur-covered membrane attached to the fore and hind limbs on each side. In the bat, the hand has become the wing, with the fingers as the supporting rods of the structure. In the flying-squirrels, however, the toes are all free. In all but an African group the parachute is supported by a rod of cartilage produced from the wrist, while the membrane bridges the gap between the hind limbs and the root of the tail, a similar extension joining the forelegs with the neck. In the scale-tailed squirrels, a family comprising two distinct genera, and confined to Africa south of the Sahara, we have a squirrel with a parachute of slightly different design. Here the skin is supported by a rod emerging from the elbow instead of from the wrist. Another peculiarity of this squirrel exists in the fact that, extending for some little distance from the root of the tail, the under side of that organ is armed with scales, an arrangement that affords the animal considerable assistance in climbing.

Whatever their other characteristics, all these flying-squirrels have much the same method of performing their aerial journeys. They cannot fly upwards from the ground, nor from a lower to a higher branch. The flight must begin in a downward direction. The impetus gained by this volplane affords the little animal power to rise slightly in the air after the preliminary descent, and also to some extent to change its course when in mid-flight. The distance covered varies with the size of the animal, from the 90 feet and upwards achieved by the lesser flying-squirrels, to from 150 to 250 which the swoops of the greater animals may cover.

The origin of these animals is a mystery. We do not know whether they preceded or were an offshoot of the non-flying squirrels, or whether they were separately evolved from an extinct form of squirrel. That they are an ancient type of animal is, however, well known; and the marvel is that adaptation has never led some master-hand of flight to evolve a more winglike parachute, enabling the squirrel to emulate the feats of the flying-fox. We may take it that that change will never come now, for unless some great catastrophe should overtake the human race and deliver the world again into the keeping of the lower mammals, the creatures of the wilds will hardly advance much further in physiological progress. Every tree that falls before the woodman's axe marks a further restriction of the frontiers of squirreldom.

This applies, of course, only to part of the squirrel tribe, for there are squirrels which do not depend upon the trees for home-making. Among the spiny squirrels are those which inhabit clefts in rocks, or dig holes in the ground. The name "spiny squirrel" implies a peculiarity of these animals—the presence in the fur of a number of flat spines, an interesting feature suggesting the foundations of the porcupine's armament. There are several other forms of ground-squirrels, the chipmunk, for example, of which we have already read. The marmots, too, are grouped with the ground-squirrels.

But the true squirrels are, of course, famous woodmen. The handsome little rover of our English woods has kinsmen all the way from Ireland to Japan, and from the north of Italy to Lapland. The American continent has a grey squirrel as well as a red squirrel; and this small gentleman in grey may in time oust our little fox-coloured beauties, as the grey rat has driven out our old black rat. It is hardier than the common red squirrel, and thrives in semi-captivity. The Duke of Bedford was the first to experiment on a large scale with these animals in England, and was so successful at Woburn that he was able to present some of the grey squirrels to the Zoological Gardens, where they have now been liberated, and are one of the chief joys of the Gardens and of Regent's Park. They rival the elephant as sturdy beggars. All day long they take toll of nuts from visitors, and with futile zeal bury 99 per cent. of their booty. It will be interesting to see if the descendants of these animals outgrow this storing instinct. Access to an unfailing supply of food must in time modify this passion for providing against the winter, which is now their motive.

The arboreal squirrels make delightful little nests in trees, planned upon the most approved hygienic scheme, and in these they pass the winter, partly hibernating. When hunger awakens them, they scurry down to their innumerable storehouses, dig nuts, or acorns, make a sumptuous repast, and return to slumber the dark, cold days away in the neatest little nests made by

THE SHOWMAN'S "GIANT RAT": A LARGE AQUATIC RODENT, THE COYPU, ON LAND AND IN WATER

ani... s. Those of us who are familiar with its engaging manners desire to see the graceful little squirrel thrive abundantly in our woods, but old legend and suspicion have been verified. In the summer many squirrels may ruin a plantation of young trees, by nipping off the tender shoots; and they are rapacious robbers of birds' nests, taking not only the eggs, as has been so long alleged, but actually the callow nestlings. Still, they have a contra account as a set-off. We owe many a noble British oak to the acorns hidden in forgotten days by squirrels who meant only to ensure a meal against some cold and barren to-morrow.

There are many varieties of squirrels, from the Indian giant, which measures twelve inches from the tip of the nose to the root of the huge, bushy tail, or the huge, woolly flying-squirrel, which is six inches longer, down to the pigmy squirrel, with a body-length of barely more than three inches. Then we get right away from the family to find a relative of a far distant date in the sewellel, which to-day has not a near relative in the world, and is restricted to a limited area of North America. It is an animal a foot in length, but with only an inch stump of tail, and it carries a head resembling that of a pug-dog. A living relic of a dim past, dwelling in moist ground, and feeding upon plants in the streams near which it makes its home, it can, by means of its tight-gripping paws, climb the lower branches of trees.

A TREASURED FUR-BEARER: THE CHINCHILLA

We come next to the jerboas, the kangaroos of the rodent family. Such characterisation refers, of course, only to the extraordinarily lengthened hind legs and to the flying leaps with which, when at speed, they progress over the ground. The kangaroo always hops, but the jerboa when moving slowly crawls inelegantly upon all-fours, resembling rather the frog or the toad, which, when advancing upon its prey or when overcome with fear, waddles upon all four feet. The jerboas are characteristic of the deserts of the Old World, and especially of Africa and South-West Asia. Their diet is, strictly speaking, vegetarian, but some species will eat eggs and even birds; while one, the Afghan species, has mastered the secret of almost complete abstention from water when in a state of freedom, though accepting liquid when captive. Jerboas kept as pets are docile and affectionate, but to confine desert animals fashioned for such boundless freedom seems rather like cooping up some wandering Arab from the tented wild within the limits of a suburban flat.

When we come, in a later chapter, to the jumping mice and rats, we shall see how the jerboa-like design has been utilised a second time. Here, however, we pass to the lemming, which is a close ally of the short-tailed field-mouse, found in Scandinavia, in Northern Asia and North America. Lemmings resemble the hamster in appearance and mode of life, dwelling in burrows, but feeding upon grass, reindeer moss, the catkins of the birch, and various roots. The chief interest in these animals is, however, associated with the manner of their death, when Fate sweeps them in multitudes to destruction. It may be noted in passing that Siberian squirrels are impelled periodically to migrations from which none returns, but the lemming's is the most oft-cited example of the crusade that knows no coming back.

The march is like that of the springboks many times multiplied, and the origin seems to be the same. It is all a matter of food, but the lemming makes its terrible march not yearly, but only once. It is the penalty it pays for excessive prosperity. A colony is started upon the mountain slopes, and speedily attains considerable dimensions. If the weather be severe and the summer not too long, the number of the animals is kept within reasonable bounds. But should spring come early and a year of special abundance follow, the increase in the lemming colony is almost incredible. Disaster may not follow until the next year,

or it may come in a long summer following an early spring. The early arrival of summer accelerates the growth of vegetation, and, with every prospect favouring, the lemmings become millions. The heat of summer scorches up the vegetation, and the overwhelming host of lemmings finds the stock insufficient. Starvation faces them. They do not set out to new grounds and then turn back, after the manner of the springboks. They set out to march to death. The migratory instinct seems to settle upon the lemmings of a vast area all at once. Now, whether all go, or whether some remain laggards, or as guardians of the old home, has not been decided. The lemmings that march out never return; and for two or three years after their departure no lemmings are to be seen in the old quarters. Then a few are observed, and from these a new colony is built up on the old site.

Meanwhile, the army that marches out forms a spectacle of which many men have written with pens dipped in wonder. In innumerable hosts they press forward, millions upon millions of them, all in column, their little feet pressing out a deep path where the myriads pass. All the food encountered by the vastly long column is eaten by the vanguard; the others throng despairingly on. They will not look at a stream in ordinary times, but now they swim lakes and rivers, cross fjords and arms of seas; they eat their way through haystacks, they crowd streets of towns and villages, they swarm through houses, they press on over mountains. Nothing stays them so long as life lasts. Messengers of death, winged and four-footed, prey upon the stampeding host; waters drown enormous numbers of them; epidemics mow them down as they march. For miles and miles the way is strewn with the bodies of the dead, and the rest struggle on until not a living lemming remains. Such is one of Nature's hideous expedients for the reduction of excessive population. Nature is a demoniac mother.

A SOUTH AMERICAN RODENT : THE PACA

We find an analogous case in the fate of the snowshoe hare (Lepus Americanus). This animal enjoys cycles of great prosperity—seven fat years in which its numbers are enormously increased. It becomes the staple food of all the North American carnivora, from man to glutton. The lordly Indian of the wilds, during the year of the snowshoe hare's abundance, forbears to track larger game. Why should he trouble when his squaw can go into the woods and knock on the head as many of these animals as are required to fill her cooking-pot? The flesh-eating animals, too, find food so easy to obtain that wolves and other preying animals leave the larger game comparatively in peace. The larger herbivores, therefore, enjoy a time of rest while the prolific hare is multiplying and filling the mouths of the hungry. And then, after the seventh year, when the wilds are alive with these hares, "the animated wheat of the woodlands," as they are called, come plague and pestilence, and their numbers are reduced almost to vanishing point. The disease passes; the animal is too scarce to make its pursuit profitable; men and animals turn to more considerable game, and the hare is left in peace and health, to increase once more until again he attains numerical proportions sufficient to become the stockpot filler and food of the carnivores.

Take, again, the strange case of the coypu, a large aquatic rodent, called by showmen "the giant rat," but more nearly resembling the beaver in certain characteristics. The Spaniards regarded it as a species of otter, and called it the nutria—which is Spanish for otter. It is by that name that the fur of this animal is known, but it is commonly sold as beaver. There was a great demand for this fur some time ago, and the coypus, whose range is limited to the rivers and lakes of South America, became very scarce. A decree was therefore published forbidding their destruction. The consequence was that the coypus changed their habits. Naturally, they burrow into banks and feed upon water-weeds, but now, no longer menaced by man, they took to the land, displayed a migratory instinct, and swarmed everywhere in search of food. Thus habit and diet were altered, and the animals throve extremely upon the change. Suddenly, says Mr. W. H. Hudson, a

mysterious malady fell upon them, from which they perished and became almost extinct.

Among the most valuable of the fur-bearing rodents are the chinchillas, little burrowing animals distinguished by the kangaroo-like length of their hind limbs, and restricted to the mountainous districts of South America and to the West Indies. The common chinchilla, which supplies the exquisitely soft fur of commerce, has five toes on the fore feet and four on the hind feet, and carries a long, bushy tail, but in the same genus is the short-tailed chinchilla, an animal of greater bodily bulk than the other, and also differentiated in the respect which its name implies. The largest of the chinchillas is Cuvier's, the fur of which, however, though much sought, is far less valuable than that of the true chinchilla.


THE PATAGONIAN CAVY, OR MARA

An interesting group of South American animals follows, beginning with the agouti and the paca. They both resemble extremely large guinea-pigs, the agouti measuring from eighteen to twenty inches from nose to tail, and the paca reaching quite two feet in length. Both are hunted for food, their flesh being considered a delicacy, a particular in which they are distinguished from the cavies. The latter are divided into four species, although the many breeds which have been evolved from the domesticated animal would suggest to the fancier that there must have been infinite resources upon which to draw. But all our tame varieties are now shown to have descended from one species, Cutler's cavy, which was first domesticated by the Incas in Peru, whence it was carried to Colombia and Ecuador, and brought to Europe soon after the discovery of America. In a state of freedom, cavies frequent marshy districts, where they are sheltered by vegetation; or sandy areas, in which they can burrow. There is one species, however, the Bolivian, which is confined entirely to the higher regions of the Bolivian Andes, where it may be found in large colonies at an elevation of from ten thousand to sixteen thousand feet.

The guinea-pig, like the ferret, prospers more in confinement than when at liberty, both animals proving much more prolific when kept as pets than when dependent for food-supply and shelter upon natural conditions. There is one cavy of which the average breeder knows nothing. That is the mara, or Patagonian cavy, a large rodent which at first sight might be mistaken for a member of the hare family or even for a small deer. It attains a length of from two and a half feet to nearly three feet, and stands over a foot in height at the shoulder. The largest of all the rodents is the carpincho, or capybara (also spelled capivara). It is a native of all South American rivers on the east side from Guiana to La Plata, and, with a length of about four feet, may weigh nearly 100 pounds. It is a piglike animal, and is locally known as the river-hog, but the superior length of its hind limbs causes it, when pressed, not to run or gallop, but to spring or leap. Although the carpincho damages the bark of young trees, it must have played an important part in keeping watercourses clear, for it feeds chiefly, when not tempted into larceny by cultivated crops, upon aquatic growths which, left to riot unchecked, might choke a river and flood the land around.

The picas, hares, and rabbits bring us to the end of our list. The picas are smallish, tailless animals, and the nearest allies of the other animals named, inhabiting Northern and Central Asia, part of Eastern Europe, and North America. They burrow and form huge underground colonies, and the Mongolian representative, at all events, has the ability to dispense entirely with liquid during the recurrent annual period of drought. Most of the picas frequent the higher mountain ranges; some in the Himalayas flourish at an elevation of as much as 19,000 feet above sea-level. The hares and rabbits have the lower levels to themselves, though we have mountain hares as well as Polar hares and wood hares and marsh hares and many another species differing in size and colour as in habitat.

THROUGH DEVASTATION TO DEAT

AN UNHEEDED BARRIER IN THE COURSE OF A HOST OF MIGRATING LEMMINGS

There is a striking contrast, for example, between the Scottish mountain hare, which turns white in winter, and the common hare, and still more between these two and the blue or Alpine hare.

Hares and rabbits form one genus, but there is much difference between the characteristics and habits of the two. The hare is born clad with hair and with its eyes open; the rabbit at birth is naked and helpless. The common hare has its home absolutely in the open; the rabbit makes such burrows as to become a public danger, even undermining highways. The hare has by far the greater intelligence of the two, and its arts in eluding the pursuing greyhound have always earned the unstinted admiration of the careful observer. Yet the same paralysing fear of the weasel and stoat is present in the hare as in the rabbit, and, like the latter animal, this paragon of speed finds itself, in the presence of its enemy, so leaden-footed that the comparatively slow-moving carnivore has not the least difficulty in catching it. The irony is that stoats and weasels, introduced into Australasia to keep down the rabbits, refuse this type of fare, and attack the poultry of the distracted settler.

Much as we read of this plague of rabbits in Australia, none of us can realise what it means; the miles upon miles of pasture ruined by these teeming rodents; the thousands of square miles of land enclosed by "rabbit-proof" wire netting; and the farmers driven to despair as their plans for the extermination of the furry locusts are defeated. New South Wales has exported 15,000,000 skins of rabbits in a single year, while in thirteen years Victoria accounted for 500,000,000. But that leaves out of account the far greater number that are poisoned, or are destroyed by the fencing in of water-holes, near which the rodents, maddened with thirst in a season of drought, die in such multitudes that their bodies form huge mounds.

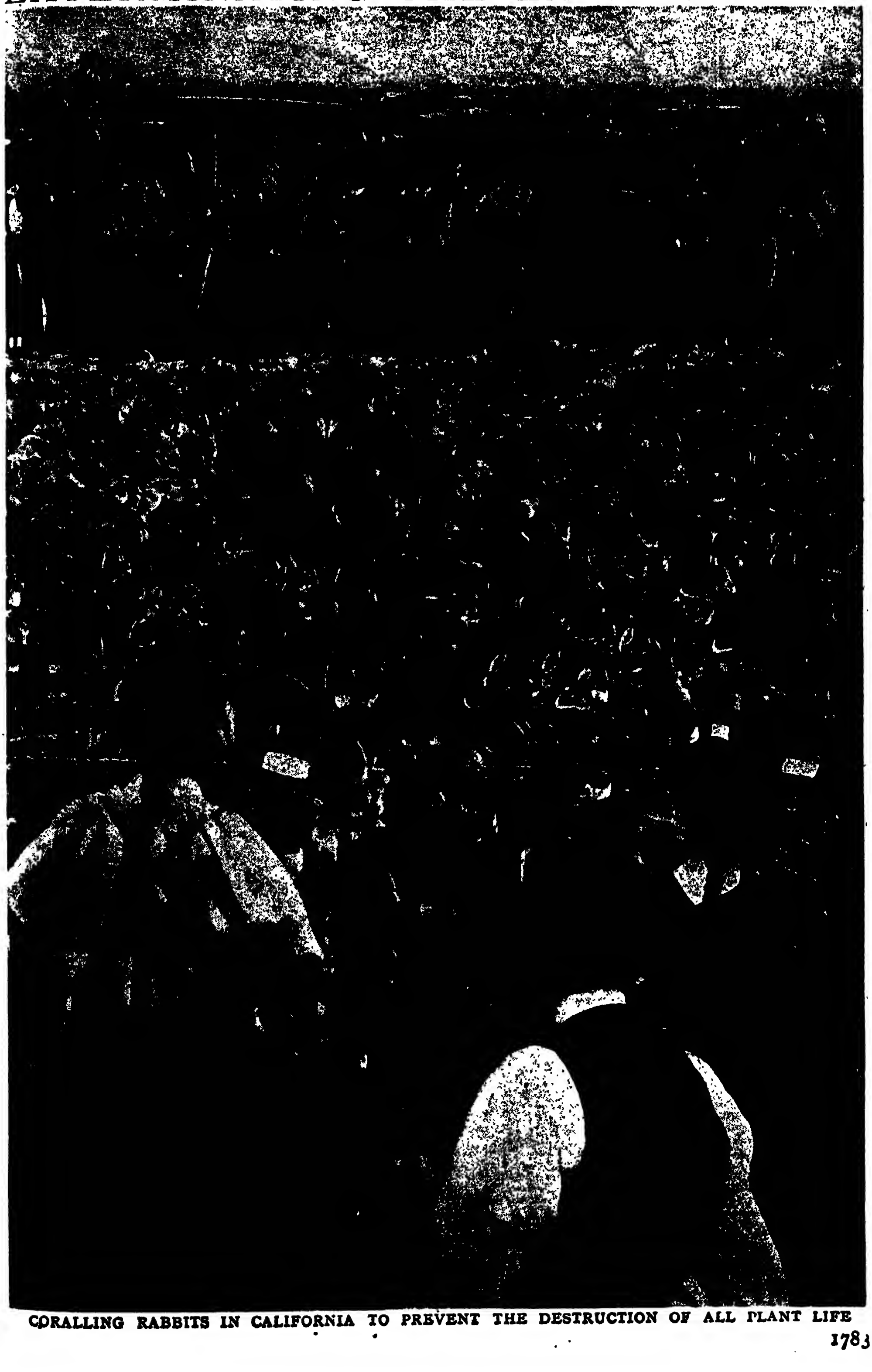
It has been shown that the cost of the rabbit plague to Australasia is about £700,000 a year. A prize of £25,000 was offered some time ago by the New South Wales Government for the invention of some positive means of general destruction, but the sum has not yet been won. Indeed, in New Zealand, where the rabbit is a more recent introduction than in Australia, these animals have become so overwhelmingly numerous that civilisation is threatened in parts, colonists having seriously to consider whether it would not pay them better to vacate certain areas and seek fresh woods and pastures new, than to carry on the war with the rodent legions which, with a relentless pertinacity, are eating them out of house and home.

THE GREYHOUND OF RODENTS : THE HARE

THE BANE OF AUSTRALIA : WILD RABBITS

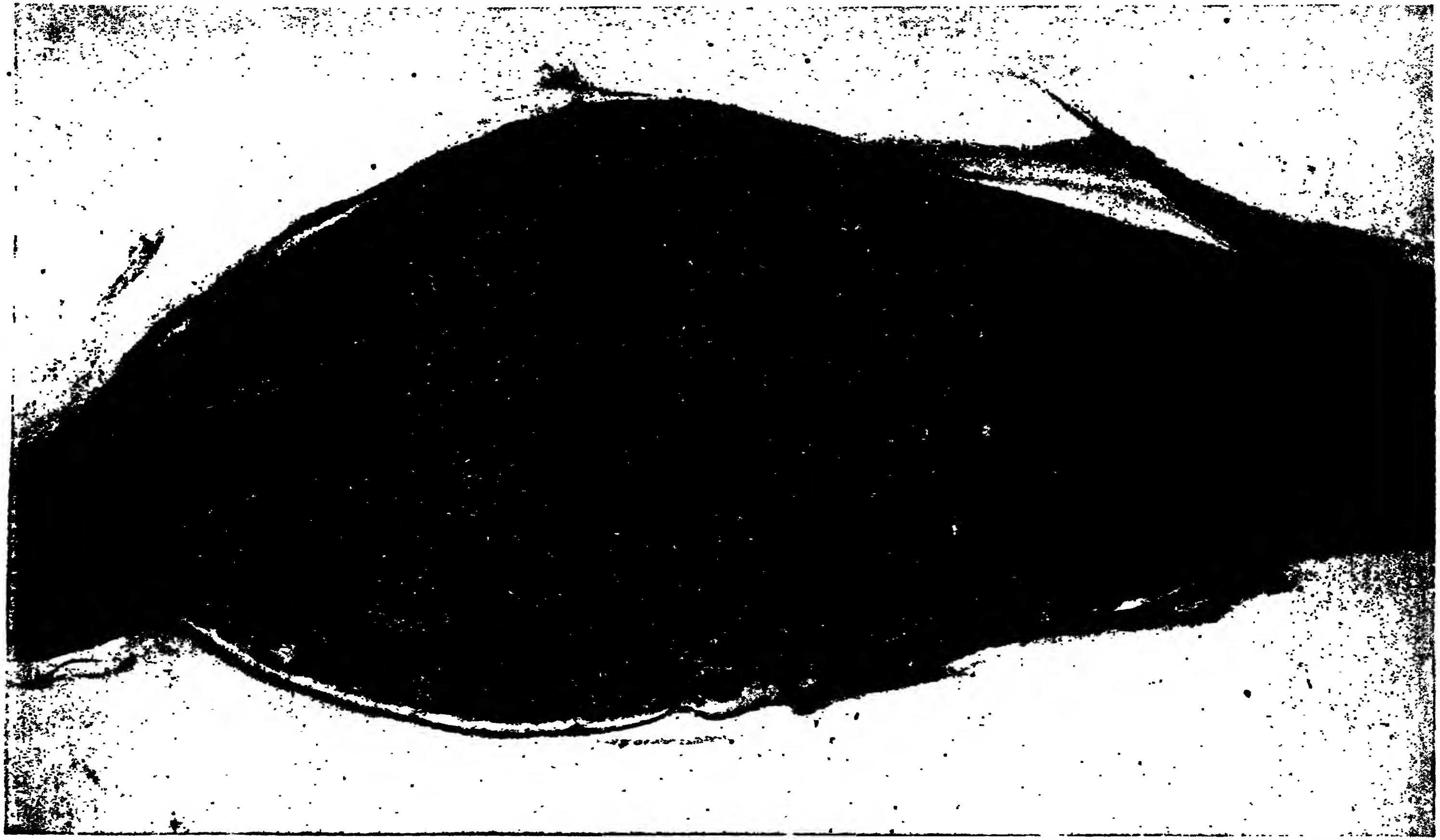
In a restricted area rabbits would probably experience a fate similar to that of the over-numerous lemmings and squirrels, but in Australia, where they have been imported in comparatively recent times, the space is too vast for such a law swiftly to operate, and there are no indigenous carnivorous enemies to keep them in check. The mind may reel at the seeming abomination of blind cruelty in the fate which dogs the lemming; but before agricultural Australasia can freely develop, man will have to invent death in as comprehensive a form for the overthrow of these parasites of his own introduction. And were he dependent upon his own unaided efforts in combating their advance, many other members of the rodent order would be as great a menace. Nature is terrible, but man could not fulfil his destiny were she otherwise.

EXTERMINATING THE EXTERMINATOR



CORALLING RABBITS IN CALIFORNIA TO PREVENT THE DESTRUCTION OF ALL PLANT LIFE

A MICROPHOTOGRAPH OF ONE OF THE MANY SERVANTS OF THE NERVOUS SYSTEM



The nervous system of man is by far the most complex of all his systems; and in this picture of a spinal ganglion, shown in longitudinal section, down its centre, and magnified fifty times, we see a kind of seat of nutrition for the nerve fibres that pass through it from some portion of the body to the spinal cord. The numerous circular ganglion cells, seen in this picture with their little dark nuclei, send fibres to unite in a T-shaped junction with the fibres passing through the ganglion.

MAN'S COMPLEX NERVES

The Nervous System in Man and Beast, and the Nature of the Difference Between the Two

MAN'S INFINITE CHOICE IN ACTION

We have now dealt in succession with the various "systems" which comprise that "paragon of animals" the body of man, and we have confidently stated the essential relation between the nervous system, the last to be reached, and all the others—that they are for it and not it for them. When all qualifications have been made, that remains true. The body is a nervous system, evolved and imposed upon circulatory, digestive, respiratory, glandular, bony, and other systems. Taken as a whole, the function of all these is to repair, protect, cleanse, and ventilate the nervous system, to make it as nearly as possible independent of external circumstances, not at their mercy, though none the less aware of and able to deal with them. But these other systems have another most important function, which is to store up energy for the use of the nervous system. A very great part of the weight and bulk of the body is made of muscles, which are the end organs of motor-nerves, and which contain extraordinary quantities, very easily replenishable, of energy in the form of sugar and allied chemical substances.

Thus the essential reason why the body of man is so complex—all the preceding chapters taken together merely outline the main principles of it—is that the nervous system desires and requires to be as complex as we find it to be. This unimaginable complexity of the nervous system is the supreme fact of the anatomy of man, because of what it makes possible for his conduct, internal and external. It indispensably serves the deeds and the thoughts of man, which are man essentially, nor could any simpler structure serve him thus so well, as we shall see. But the more complex the nervous system, the more withdrawn from the outside world, and yet the more closely and subtly related to and responsive to the outside world, the more does it need by way of support and ventilation and chemical and mechanical appliances and apparatus. Hence the complexity of the body, the amazing number of specialised cells and organs which have been added to it in the course of evolution. Each of these new parts, unlike a lifeless piece of apparatus made by man outside his own body, is itself alive, and has its own requirements. It reacts on other parts, and they react on it, so that there is no end to the complications, and indeed we have only begun to unravel the crudest part of them, though the body has been anatomised and analysed millions of times. But with all this complexity there remains a no less wonderful simplicity of meaning, and of consequence. For the body, with all its details, exists for the purposes of the life of man, which consists of some kind of action. Let us look at the nervous system afresh from this point of view.

Or, rather, let us first understand what action involves, and how it evolves, in the history of that branch of life of which man is the highest and growing point. And as we trace action, conduct, response, in broad outline, we shall observe how the nervous system appears and evolves correspondingly, requiring more and more of the other arrangements we have already described, until at last we see what the body of man is from the standpoint of a true theory of evolution. We trouble here no longer with the nineteenth century view that the body of man is composed by the accumulation of a vast number of chance variations which persisted and stuck together because they were advantageous. We see clearly that the body is crammed with purpose, and if we would interpret it correctly we must realise what that purpose is.

Purpose is a great word. We do not here mean destiny or purpose in the highest sense. It is quite enough that we should recognise, at this stage, the immediate purpose of the body of man, which is *action*. This is, of course, true of the body of any animal; and it is in the comparison between bodies and nervous systems (when they appear) from the lowest animals up to man that we begin to see why man's actions, conduct, behaviour so transcendently excel anything that his ancestors and allies display. Action is for life, or life is for action; and it is idle to pretend that there is any fundamental difference, in the bases of conduct, whether we observe them in the amœba or in man—in the one-celled animal that has no nervous system, or in the animal whose nervous system alone contains thousands of millions of cells. To move towards and to swallow food is a kind of action common in all essentials to amœba and to man. The machinery is very different, but the action, the purpose of the action, and the need of the action are precisely the same. The man, with all his complexity, is thus just as simple as the simple amœba so far.

How Man is Exceedingly Different From and Exceedingly Similar to the Lower Animals

Therefore, if we are to understand man, and the meaning of his nervous system, we must trace action upwards in the history of life, and we must try to keep our heads amid the two temptations to which so many of our predecessors have succumbed. They are quite obvious, but none the less perilous, somehow. One is to insist upon the agreement between man and the lower animals, of which there are so many staggering examples, like that already furnished, and to conclude, in short, that the difference between man and the lower animals is one only of degree; not great even at that, but of kind not at all. The arguments for this view are many and easy and satisfying, and lead to the precious conclusion of Beaumarchais, that man differs from the lower animals only in that he eats when he is not hungry and makes love at any time.

The other temptation, just as commonly succumbed to, is to declare that man is so wholly unique and apart that to introduce any comparison between the springs of his conduct and that of the lower animals is to dishonour him and to know nothing of him. The arguments for this view are just as many and satisfactory as for the other. The only condition, in either case, is that one shall know what one wants to see, and shall look only at the evidence in favour of it. But the real truth is the evolutionary one, which we are now beginning to perceive, that man is exceedingly different and exceedingly similar to the lower animals, both in body and in function, which ultimately means behaviour.

Unlike either of the half-truths, above indicated, which respectively dishonour either man or the lower animals, the whole truth honours him without dishonouring them. We may freely recognise, in the nervous system of the dog, for instance, a structure which seems suitable for the display of intelligence, and may unreservedly admit the display of intelligence in the conduct of such an animal, without for a moment regarding Beaumarchais' definition of man as anything but a vulgar, if funny, falsehood.

Similarity Between Man and the Simplest Organisms in Procuring Energy

Let us see, now, whether these large statements can be justified. The body is a machine for action. The action requires energy and apparatus, and so forth, according to the laws of physics, but the object is simple, and it is realised by the very simplest organisms we know. The amœba is aware, and replies. Its life essentially consists of two processes—first, procuring a supply of energy; and, second, spending it as it will. So, also, does the life of man. Let us see how the evolution of a nervous system, and, above all, of man's nervous system, affects these two processes. As regards the first, we shall not trouble, being intent to note its essential character, for man as for the amœba. The differences that exist between the two in this respect of getting matter little; it is the difference in the respect of spending that matters everything.

The Reflex Action of the Least Developed Living Thing not Wholly Mechanical

There is no doubt that, until very recently, men of science have underrated amœba and such humble forms of life. But it is still true that, in the main and essentially, their behaviour is *reflex*, as we say, and very little more. It is vastly important for our philosophy that there *is* a little more, but it is only very little. For the rest, the action of the amœba is reflex. And here we meet a phrase, "a reflex," or "a reflex action," which is of enormous importance in the study of all forms of animal life, and, above all, in the study of the nervous system. The term is

not used as strictly as it should be, and different authors often arouse controversy and misunderstanding in consequence. But we mean by it an action which is so constant and rigid and automatic, to all appearances, that it may almost be called a reflection, like, say, the rebound of a billiard-ball from a cushion. If the cushion has "acted," its action is certainly a "pure reflex," constant and automatic.

Now, we shall do well to rid ourselves, from the first, of the idea, still held by all but the most profound and advanced students, that any reflex action is wholly and truly mechanical, like the "reflex action" of the cushion of a billiard-table. To call it a reflex is only to use a bold metaphor.

Reflex Action Always Involves the Psychical Fact of Sensation

Life is always involved, as we see at once when death supervenes, or the death of the particular nerve-cells involved, if such there be, or when fatigue or intoxication, by anæsthetics or otherwise, abolishes what we call reflex action. The reflex may be extremely simple, it may be invariable, it may look like the response of a machine, but that is only because life is using machinery for its purpose. The climb from reflex action up to the action of the human will is not a climb from unconsciousness to consciousness, nor from machinery to life. In the humblest and simplest and oldest reflex action or response of life there is always necessarily involved the psychical fact we call *sensation*. The law, "No sensation, no reflex," is absolute. The hair of a living animal, or even of a dead animal, may be pulled, and the skin will return when the pulling ceases. That is elastic response, purely mechanical and independent of sensation. The hair of a living or a dead animal may burn when a match is put to it. That is chemical response, equally independent of sensation. But if the animal be alive, and not poisoned, asleep, or otherwise put out of action, it may *feel* in these cases, and may exhibit a reflex, biting in the direction of the pull, running from the match, or what not.

Sensation the Very Basis of Life—Especially the Life of Man

You may also stand beside a motor-car, touch a lever, and it will run away; and there we see the mechanical imitation of a reflex action, or the mechanical apparatus of a reflex action. But a real reflex action is a vital act, involving sensation.

Sensation lies at the very basis of all life above all, of the life of man. We shall study it as a whole before we proceed to study the special forms of apparatus which he possesses for special kinds of sensation. Meanwhile we simply assume sensation for the present purpose. We shall rightly talk of reflex action as automatic, as largely mechanical, as rigid, as involuntary, and so forth, but all the while we shall be assuming, because we must, the existence of a psychical fact, which is eternally different in order from anything that those adjectives suggest, and which is called sensation.

Now, the amœba feels and responds, though it has no special organs of sensation. It need detain us no further. The next stage that needs description simply shows us a special machinery for feeling and replying, which we call nervous. It is not evolved all at once in this form, but we may pass over its rude sketches, and look at the form which we find in all but very humble animals, and which occurs in millions in the nervous system of man. It is called a reflex arc, or a sensori-motor arc. Not long ago distinctions were drawn between the two; the reflex arc was said to serve a reflex act, in which there was supposed to be no sensation, or only an "unconscious sensation." Such a term is an absurdity; for we know that if any supposed reflex arc, not needing sensation, be treated so that no sensation can occur, no action will occur. That suffices, and we shall not draw a distinction which does not exist, and could not exist.

Sensation Occurs Accompanying Action in the Very Humblest of Organisms

The typical reflex or sensori-motor arc, such as we find in our own bodies, will consist of a sensory half, and a motor half, together with any necessary machinery. A sensory nerve will run, from the skin or the eye or anywhere else, to some central point, from which a motor nerve will run to a muscle (which is merely the end organ of a nerve); and when a stimulus runs to the centre, along the sensory nerve, and a consequent sensation is felt in the nerve-cell of that sensory nerve, an order will be given by the nerve-cell of the motor nerve, so that a movement will occur—the eye, threatened by a blow, or needing the moisture of a tear, will wink, or any such simple reflex action will occur. The anatomical details of the machinery do not much concern us. Few or many nerve-cells may be involved. The movement need not be that of a muscle, for it may be movement in the cells of a gland that secretes saliva or tears or what not—as when our mouth "waters" at an

appetising odour. The sensation may be of any kind, the motor response may be of any kind, but still the act is essentially a reflex or sensori-motor act, performed by means of a nervous arc.

If we look at the nervous system of man, as a whole, we shall find it hard to believe that there is any particular resemblance between so complicated and various an apparatus, and anything so simple as the reflex arc of the diagram. Yet we can historically trace the evolution of the nervous system, from his ancestors up to man, or from the first to the mature stages of the individual man, and satisfy ourselves that this is, essentially, a number of sensori-motor arcs, no more and no less.

Anatomically the Nervous System Exists to Control the Body

We might imaginably replace all the sensory fibres and cells by one, all the motor fibres and cells by one; and we should have everything that is essential in the nervous system. To it we should require to add a variety of machinery for other purposes, but that would not be essential. If we are to have a heart, and lungs, and so forth, these and other organs will require nervous control. Then, of course, anything so complicated as the body will require much controlling machinery if its parts are to act as a whole. If, therefore, we look at the nervous system anatomically, and without any clue, we shall think of it as existing in relation to the rest of the body. We shall observe the nerves running to and fro between all parts, and we shall insist that the nervous system exists to control and co-ordinate the whole, to supervise the nutrition of the various organs and keep them in touch with one another.

Now, it is true that the nervous system does all these things, and many more; and it has often been described in these terms, especially by the physiologists, who unravel its relations in the body, and the multiplicity of its functions.

The System that Exists to Converse With the Outer World—to Feel and Reply

Yet so to describe it is to miss the whole point. The nervous system is essentially a sensori-motor or reflex apparatus—with modifications, as we shall see—which exists for converse with the outside world. It is required to feel, to perceive, to remember, to consider, to reconsider, to ignore, to refuse, to delay, but finally, and in the upshot, to reply—even by not replying. The natural sequence is to feel and to reply. The other terms we have inserted are very important, and explain why the nervous system is really so complicated. But, however many terms and stages and varieties of psychical action we interpose between sensation and response, these are the two essential terms.

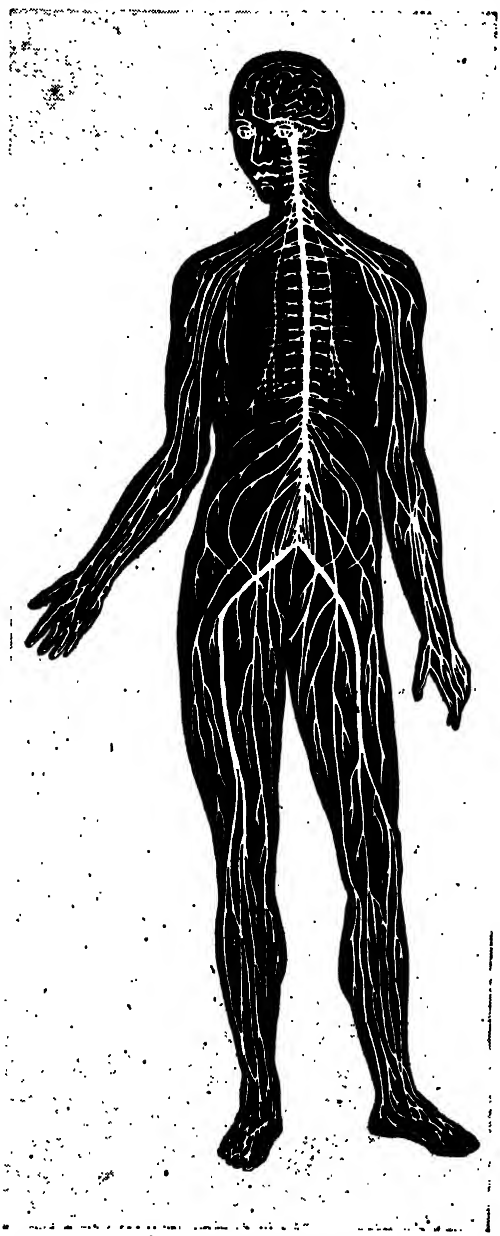
And, as a matter of fact, simple acts, involving only these two terms, are constantly being performed by the nervous system of man, just as in the humblest kinds of nervous apparatus that are known. The sensory stimuli, as they are called, may proceed from the outer world, or from the inner outer world, which is the rest of the body—outer to the nervous system, but not outermost. The replies may involve only some act in the body (which is, so to say, the immediate environment of the nervous system), or may involve some act upon the really external world. But the act is essentially reflex or sensori-motor. We could not maintain our lives for more than a few seconds if these reflexes were not constantly at work. *We* are not aware of them, and from *our* point of view we may call them "unconscious" or "automatic" or what not, but some of our nerve-cells are certainly aware of them, as we should realise, only too well, if those nerve-cells failed in their duty. The problem of drawing great distinction between such of our nerve-cells and ourselves is too difficult for the nonce, and may fortunately be deferred.

The Almost Infinite Activity of the Nervous System—Conscious and Unconscious

The fact remains that the nervous system, alike during sleep and waking, attention and inattention, conscious activity or repose, without intermission from its first antenatal activity until death, is always performing an almost infinite variety of reflex actions, without our conscious assistance—which, in many cases, would be disastrous, and, in many others, is actually impossible. We have said *almost* infinite, and the qualification is necessary. When sensori-motor arcs are to be numbered by millions, and when almost any sensory half may be combined with almost any motor half, obviously the number of actions is enormous, but it is neither infinite nor indefinite. All these actions are anatomically conditioned. They depend upon the machinery that exists; and though that machinery is very adaptable, it has its limits. It is not until we reach the highest and latest part of the nervous system, which what we are now describing merely serves, that we shall reach the possibilities of the infinite.

We shall see, in due course, how this machinery becomes developed in man, so that he is capable not only of complicated actions but also of delay and reflection and invention and introspection. But no psychology, scientific or mystic, can obscure the truth which modern study of the nervous system and of man as a whole so clearly teaches—that the nervous system is sensori-motor, made of action. All sound systems of thought, and even of ethics and religion, have preached this truth.

Stoicism may have denied it, but stoicism has always led to its own destruction, as such a suicidal doctrine should. The other systems have taught that man must feel and must act, that the highest type of man is he who feels deepest and acts best, that merely to feel and not to act is contemptible or dangerous. It is not good to cultivate sensation for the sake of sensation, emotion for the sake of emotion, or art for art's sake. These things exist, and have their ultimate justification in conduct. Tragedy, as Aristotle said, should purge the soul with pity and terror, so that its deeds are fairer thereafter—not that we may say "How thrilling!" and go away with our conduct as selfish and pitiless and proud as ever.



THE CEREBRO-SPINAL NERVOUS SYSTEM OF MAN

Such, very briefly, is the ethical teaching of this theory of the nervous system. Its biological teaching is no less clear. Life is something that tries to act on inert matter, and achieve a purpose of its own. This it does in plants that have no nervous system, in animals that have none, and in those that have. It is just the same in man. His nervous system is simply the finest apparatus of the kind hitherto evolved. Our problem is to state its special qualities without losing hold of the anatomical facts. It has all the reflex possibilities, in the first place. Its many sensori-motor arcs are so evolved that the nervous system is capable of feeling and of responding automatically in a vast variety of ways. In the spinal cord and the lower part of the brain of man we find a large number of "nerve-centres," each of which is a group of cells that may be "got at" by a variety of sensory paths—from the eye, the skin, the stomach, the ear, and so on. These motor mechanisms, which we have not constructed for ourselves, are at our disposal. They wait only for a signal to release, or set going, the corresponding action. Thus we strike or cry or laugh or flinch or walk or breathe or utter or grasp—and so on—through a long list—by setting these prepared nervous mechanisms in motion, or by letting them go. In ourselves their number and variety and their modifiability and adaptability are unique.

But, as we shall see more clearly when we come to study the will, this part of the nervous system constitutes only one half its excellence in ourselves. Above—literally above, when we stand in the "erect attitude"

—this unrivalled assemblage of sensori-motor mechanisms is a newer, subtler apparatus which is the machinery of the will, and it is will that determines what use the prepared mechanisms beneath it shall be put to. Indeed, the will is quite capable of manufacturing new mechanisms by modifying the old ones, and re-piecing them, so that we learn and acquire all sorts of habits, good, bad, and indifferent. Short of that, the will is concerned either to choose the particular mechanism it will employ, or to combine them for special purposes; and it can decide at what moment it will release the machinery. Many of our acts are thus voluntarily delayed reflexes; we did not strike our enemy when we might, but we "get back" on him later. And thus the will of an animal, and pre-eminently the will of man, "is the more effective and the more intense, the greater the number of mechanisms it can choose from, the more complicated the switchboard on which all the motor paths cross, or, in other words, the more developed its brain. Thus, the progress of the nervous system assures to the act increasing precision, increasing variety, increasing efficiency, and independence. The organism behaves more and more like a machine for action, which reconstructs itself entirely for every new act, as if it were made of indiarubber, and could, at any moment, change the shape of all its parts."

The Infinite Choice by Man in Action through the Complexity of his Nervous Development

This, we observe, the amœba itself can do, but man displays this fundamental property of animal life in almost infinitely—perhaps in infinitely—higher degree. In him the power of choice is unique; and that is another way of saying that in him consciousness reaches its highest point.

Consciousness appears the more when creation and choice (which are closely allied) become possible; it lies almost dormant when life is condemned to automatism, and we are not ourselves conscious of our automatic acts, even though nerve-cells somewhere must have felt, for their performance. Choice and consciousness, at their highest in us, and in us at our highest, are proportional to the complexity of the switchboard on which the paths called sensory and the paths called motor intersect, or the switchboard from which they can be controlled and recombined. That switchboard is the human brain, the characteristic organ of man, unique in its development in him.

But before we try to estimate the distinctive property of this "switchboard," let us be sure that we appreciate the importance of the machinery it controls. We cannot do so without a few preliminary words on the great subject of instinct. Perhaps the most serious criticism that can be passed by the biologist upon Bergson's estimate of human psychology is that he underrates, without, of course, ignoring, the importance of instinct. We must allude to that point here because of the celebrated interpretation of instinct which we owe to Bergson's great predecessor, Herbert Spencer.

The Undervaluing by Bergson of Concealed Reflex Action in Man

The argument of our present chapter is that, no matter whether we look at the nervous system with the microscope, or whether we observe its mode of action, we are compelled to recognise in it a reflex or sensori-motor machine. We have further seen that reflexes may be put together, co-ordinated, compounded for the performance of acts that remain essentially reflex, but may yet be so complicated and detailed and prolonged through successive stages that their essential character is almost hidden,

Now, such acts are, in fact, just those which we call instinctive, and hence Spencer taught us to look upon an instinctive action as a "compound reflex action."

Nothing in Bergson's argument really excludes this view that, considered from the evolutionary aspect, as also considered anatomically, an instinct is a compound reflex. His description and interpretation of the nervous system includes such an explanation of the physical aspect of instinct. But, as we shall see later, Bergson pays little heed to instinct in man, chiefly because of his now celebrated argument, discussed in another section of this work, that instinct and intelligence are fundamentally distinct, and have run along different lines of evolution, instinct culminating in the social insects, and intelligence in man. All that must be granted, and is a great contribution to thought.

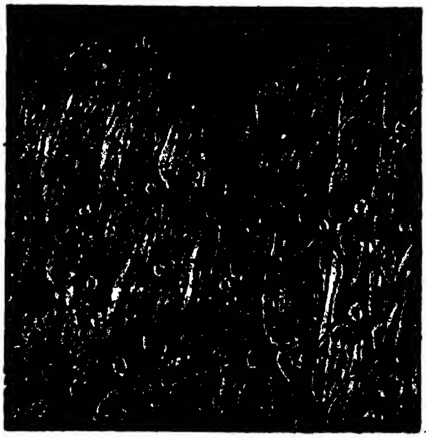
The Inadequate Reverence Paid by Scientists to the Instinct Retained by Man

Bergson also argues that a certain portion of instinct, derived from the original powers of unevolved life, remains in the vertebrates and man, just as traces of intelligence may be found in the insects. But it is very probable that, if Bergson should study the work of our own thinker, Dr. McDougall,

which must later be discussed at length, before publishing a new edition of his "Creative Evolution," he would modify his argument to the extent of admitting much more of instinct in man than he did when his book was first written, before Dr. McDougall's.

For it can no longer be doubted that human psychology has vastly underrated the importance of instinct in man, so much so as almost to admit the sexual instinct and no more, which is truly absurd, and has popularly led to very inadequate reverence for instinct in general.

The fact is that we may grant Bergson all he says about intelligence in man, and yet may allow man far more in the way of instinctive endowment than used to be supposed. The intelligence, and the highest parts of the brain, are not therefore of less account. The contrary is the truth. They are of more account because, according to Bergson's own argument, they have so many and potent and various motor mechanisms, essentially instinctive, to combine and control and choose amongst. As we shall show later, to deny these instincts is to leave the master of the house with no servants, and the will "free," indeed; but impotent. And the truth perceived by Herbert Spencer remains, that an instinct is essentially a compound reflex action. We shall see later that, as Dr. McDougall has shown, the action also has a side of *feeling*, and that this feeling, which we call emotion, and which is the inner side of the instinctive act, has been hitherto misunderstood for lack of this simple interpretation.



THE NERVE-CELLS OF THE BRAIN

This diagram represents a tiny speck of the grey matter of the brain, which resembles a telephone exchange with its myriads of nerve-fibres that link up the messages of our senses and the current of our thoughts.

But though the earlier evolutionists missed that, they were right when, through Spencer, they saw the evolution of instinctive from reflex or sensori-motor action. Only let us remember that instinct has its side of *feeling*, and we shall not run away with the too popular view that instinct is *simply* automatic, and that animals are therefore *automata*, as Descartes supposed, and may be treated as such. That is a stupid view, and anti-evolutionary in the extreme, leaving the *psyche* of man without any natural origin.

Yet, though the continuity between man and the lower animals along the vertebrate line is real, and though the nervous system of man is essentially a group of sensori-motor arcs for action, yet it does overwhelmingly transcend all its predecessors. The brain of man is so large that the quantity of choice, and of consciousness, which can be displayed through it is unique. But that is not all.

It really looks as if the brain, in man, had reached a point of capacity which causes it to differ in more than degree from its nearest rivals. Take the highest ape, and we find that, though the creature is intelligent, and can learn, its powers and learning are strictly limited. In man, as in the ape, the brain is made to choose among the various motor mechanisms, essentially sensori-motor arcs, over which it presides. But the evident fact of man is that he can learn to do anything, as is finally evidenced by the fact that he can make any kind of object, including any kind of machinery or device, an engine or a book—which is a sort of engine, too. Hence the brain of man alone can set up an infinite number of mechanisms, so that its choice as to their employment is infinite, too. Only of a brain which can create machines outside the body could this be said. The difference, therefore, between man and his nearest rivals is the difference between the limited and the unlimited, the closed and the open. It has become a difference not merely of degree but also of kind.

In reaching that great conclusion to the argument which began with the simple reflexes of any living being, we have also reached a fresh beginning.

We have come to the human at last, as distinguished from what is common to man and to many other creatures. The brain holds the key to all that shall follow; and this supreme organ of all life must next engage such capacities as it displays in us who write and read.

NATURE'S FATIGUE AFTER WORK & PLA'

NOONDAY REST IN THE HARVEST FIELD, PAINTED BY JOHN LINNELL

THE SLEEPING SPORTSMAN, PAINTED BY GABRIEL METSU, THE FAMOUS DUTCH ARTIST

WRONG KINDS OF EXERCISE

The Grave Danger of Overdoing Athletics and Permanently Injuring, Instead of Strengthening, the Body

TRUTHS AND FALLACIES ABOUT EXERCISE

NEARLY a decade ago a leading German authority expressed the opinion that there was not a single professional cyclist in Germany with a sound heart. The present writer saw enough of the results of over-athleticism in his schoolboy and undergraduate days to make him always anxious to warn the public against these dangers. The long necessary reaction against this long-continued excess is now at hand; and before we discuss the science of the matter, which is of very high physiological interest, we may note the results of the most exact and recent inquiry in this subject. Those of us who have long been protesting, in the name of hygiene and the balanced development of youth, against spectacular and competitive athletics, at any rate in their customary form, cannot but welcome the recent report of the Bureau of Medicine and Surgery of the American Navy, the verdict of which is that the prolonged and rigorous course of exercises necessary for excellence in athletic contests is injurious in its after-effects. As no such inquiry has ever been made hitherto, it is certainly worth while to preface our present discussion with some detailed statement of the results.

The records of 625 athletes of the Naval Academy classes, from 1891 to 1911, were examined in order to determine the bearing of early athletics on physical efficiency in after life. Of these, 21 died—6 from tuberculosis, 8 from mental and nervous disease, 5 from alcoholism, 1 from acute dilatation of the heart, and 1 from valvular disease of the heart. The last two deaths were directly attributed to running, and one death was due to a football injury. Of the remaining 604 athletes in the Service, no fewer than 198—that is to say, just about one-third—have had disabilities noticed in the official records to which athletics stand in a possible or probable causal relation. "Impaired service" is the verdict, therefore, on one-third of the survivors of athleticism thus abused. Of these 198 men, 48 had morbid conditions of the heart and blood-vessels, as any student of these matters might well expect; 11 had morbid conditions of the kidneys; 17 had tuberculosis; 16 had nervous weakness; and there were actually 25 cases of appendicitis and 15 of hernia, both of which conditions seem to be specially associated with a football record. The conclusion is further reached that long-distance racing is particularly likely to be injurious.

This unprecedented inquiry, the results of which will greatly surprise many people, fond parents and others, exactly confirms, on the evidence of impartial records, the opinions which some of us have been expressing for years. It is particularly to be noted that the observers were the qualified medical officers of the Service, certainly with no professional bias against athletics, and certainly with a strong professional desire to make and maintain physical efficiency in the men under their charge. This is an entirely different kind of evidence from the opinions, however accurate, of gentle, elderly ladies, long-haired poets, or those with a temperamental bias against the joys of youth. Plainly, nothing can stand against evidence like this, except a similar inquiry, on a still larger scale, which should reach opposite results; and we shall have to wait a long time for that.

Be it observed that the results of physical exercise of the wrong kind here recorded are physical results. In our present analysis and explanation of the evils of over-athleticism, we shall definitely divide them into two categories—physical and mental. It has already been argued that, for the philosophic hygienist, the influence of anything whatever upon the mind must be the final criterion.

Yet even for those who do not admit so much, and who argue that not only the first, but also the last, need is "to be a fine animal," let it be noted what a very unsatisfactory kind of animal over-athleticism produces, quite apart from any injury to the mind. The methods of physical development which ruin the most essential parts of the physique, from the heart onwards, surely stand self-condemned. The truth is that even physical exercise requires to have brains put into it, unless its own ends are to be defeated.

The Increasing Unimportance of the Muscles of Muscularity

Most of the voluntary muscles of man are almost daily becoming less important, as modern invention supersedes them. But certain of the involuntary muscles retain, and must always retain, their primeval importance. Of these, the foremost is the heart, far and away the most important muscle in the body. The remarkable lack of brains in our modern notions of exercise, so unlike those of the ancient Greeks, is nowhere better illustrated than in the drill regulations of our own Army, only just abolished, wherein no end of trouble was devoted to enlarging the size of the soldiers' chests. A series of disastrous exercises was invented, which made the chest abnormally rigid in a state of sham expansion, which evolved very serious strain upon the heart. After many years, when many thousands of recruits had had their hearts damaged more or less permanently by this absurdity, and after a few Army doctors had braved and incurred official displeasure for protesting against it ("Medical advice is a very good thing—when it is asked for," said Lord Wolseley), the regulations were altered. But they remain as an admirable illustration of the brainless and disastrous type of physical exercise.

The Folly of the Military Craze for Chest Development

The whole and only value of the chest is that it shall be mobile. Its value is not in its absolute dimensions, small or great, but in the difference between its maximum and its minimum dimensions—a difference which physiologists term the "vital capacity." As we get on in years, the chest always slowly but surely enlarges, owing to the gradual loss of the elasticity which should restore it to its smallest size in the course of each expiration. This ultimately leads to stagnation of air and blood in the lungs, and strain upon the heart. The great achievement of our Army for many years has been to anticipate in a few months of drill the effect of half a century of ordinary life, thus producing a senile chest in the soldier's early twenties. Many of us have been drawing attention to this fact for years, and now the results of the inquiry in the American Navy have come to supplement this instance from our own Army.

But if this be the kind of evidence which we find when we study the young man, what shall be said of the evils of over-athleticism in the growing boy? Here, of course, the evidence is not merely similar but still more serious. While in many modern girls' schools the great effort is to imitate boys in every particular, to play all boys' games, and play them hard, our inquiries are showing that the cult of athletics in our "best" schools often has the most serious and lamentable physical results, even for boys who are certainly not overtaxed in any other way, who live in pure air, and have plenty of nourishing food. If this be so for boys, it must certainly be a still more serious risk for girls.

The Fallacies of the Popular Proposition that Change is Rest

As always, a competitive system of this kind is judged by those who set the pace for the others, and can stand it. Naturally endowed with fine physique, they are regarded as splendid products and illustrations of the value of the system—which is not even true; and nothing is heard of the much larger number who, in the endeavour to keep up with these few, have been more or less seriously damaged, often for life.

A very powerful and very necessary reaction is now beginning against these ridiculous excesses, which begin by denying the first fact of childhood and of all life—that individuals vary in natural capacity for anything and everything, and cannot be subjected to uniform treatment without injury to many. The familiar type of man who meets criticism of this kind by saying, "It did me no harm," is doubtless correct, but when he wishes us thence to infer that it did no one else any harm he is certainly wrong.

It is a very evident and important truth that "change of occupation is rest," but it is a truth that requires more accurate analysis than it usually receives. It has been most egregiously worked to death in connection with athletics, especially in relation to school life. Those in charge of young people, of both sexes, alike in schools, reformatories, training-ships, and elsewhere, have seriously gone to work on the assumption that brain-work and physical exercise

are wholly independent. It has been seen that the boy who was tired out with books and figures was yet quite evidently fresh and fit for keen activity out of doors when he was released. We may freely grant that change of occupation is the best rest in such a case, for the sufficient reason that the muscles of accommodation in the eye, many parts of the brain, and certain groups of body muscles, formerly hard worked, now receive absolute rest. They alone were strained, and now they rest—the formula about change of occupation means no more, in such a case, than that very simple proposition.

But next we have proceeded to assume that our formula, which really means so very little, works in the other direction. After physical exercise, the young people are set to brain-work again; not only young people, indeed, for thousands of brain-workers have tried the same plan with themselves. But in point of fact it does not work at all. Especially does it fail, as a recent Congress on Educational Hygiene showed, when the physical exercise has been something in a gymnasium, under the direction of a stern disciplinarian, say a retired sergeant-major.

What Men Have Learnt from a Study of the Chemical Effects of Fatigue

That is an extreme case, but what we are stating is true, in its degree, of all cases where the physical exercise really involves any fatigue. If the writer, when his arm is tired, or the reader, when his eyes ache, takes a turn in the garden, and, in fact, gives absolute rest to the over-tired organs, that is another matter. But real physical exercise, of any kind, involves fatigue; and no sooner does the physiologist study fatigue than he learns that this is a bodily condition which has a definite physical basis, and directly bears upon the working of the brain.

The late Professor Angelo Mosso, of Turin, was the greatest student whom this subject has ever had, and his classical treatise "Fatigue," which can be obtained in English, might well be consulted by the reader. No one who had thus possessed himself of our scientific knowledge of this matter could ever again subscribe to our ordinary practice, above all with growing boys and girls, at the best-reputed schools. Mosso showed that fatigue has a physical, or rather a chemical, basis, which consists of certain poisons or fatigue-toxins, produced by the muscles involved in the exercise, and conveyed thence, by the circulation of the blood and the lymph, to all parts of the body, including, of course, the brain. These poisons are very real. It can be shown that hard work of the legs tires the arms, simply by distributing to the arms a proportion of the fatigue-toxins produced in the exercised muscles of the legs. This, of course, would not be so if fatigue were merely exhaustion of the nutriment or energy supply in the muscles. In that case, fatigue would only concern the muscles actually used; and we should not have on record the notable observation of Mosso—that all the symptoms of fatigue can be induced in a resting dog by injecting into it a portion of the blood of a dog that has been well exercised and is itself fatigued.

The Study of Microbes in Relation to the Training of Athletes

On the ground of the production of these fatigue-toxins, there is quite possibly something to be said even against the eating of the flesh of animals that were fatigued when they were slaughtered. More recently, those in this country and elsewhere who have followed up the work of Mosso have shown that what athletes call training is mainly, if not wholly, a method by which the body acquires, through exercise, an immunity against the fatigue-toxins, just as it acquires immunity against many drugs, and against the poisons produced by many forms of disease-microbes. That doubtless explains the fact that modern trainers absolutely interdict alcohol, in any shape or form, to those under their charge, for alcohol is well known, through the experiments of Professor Metchnikoff, at the Pasteur Institute in Paris, to interfere with the production of immunity to all forms of disease-poison yet experimented with, doubtless by its retarding influence upon the action of those ferments in the body which produce the anti-toxins or antidotes to the poisons; and a similar action no doubt is effected upon the response of the bodily chemistry to the formation of fatigue-toxins.

The Reason Why Vigorous Exercise Impedes the Working of the Brain

This conception of fatigue as toxic, which is no longer a speculation, but a definite result of modern physiology, must never be forgotten when we deal, practically or theoretically, with the problems of physical exercise, and it makes plain much that was formerly obscure. It was not in the least evident why exercise of the muscles of the legs, as in walking or running, should definitely impede the working of the brain, and of parts of the brain that have nothing at

all to do with the direction and control of voluntary motion. But now the explanation is clear; and while much truth is doubtless expressed, loosely and obscurely, in the saying that a change of occupation is the best rest, we must beware of applying that theory in practice without discrimination. After hard physical exercise the whole body needs rest, because the whole body is being flooded with fatigue-toxins. It is well known that, in extreme physical fatigue, even digestive rest is required, for very often if a hearty meal be taken during severe fatigue, it is found that the digestive organs, which were not themselves involved in the preceding exercise, nevertheless behave as if they were exhausted, and will not work.

The Right Relative Positions of Brain-work and Physical Exercise

Brain-work, however hard and intense, involves the production of only very minute traces of chemical waste products, far too slight to effect any influence upon the motor apparatus. Hence, the familiar doctrine already quoted happens to be right when the transition is from brain-work to physical work, and wrong when the change is in the other direction. Already in the regimen of the young, these important physiological findings are being attended to, and wise adults will soon begin to attend to them on their own account. The work of young people must be so arranged that the severest forms of brain effort, above all the actual acquirement and digestion of new knowledge, shall be attempted *before* the chief physical exercise of the day, and not after it, as in the daily curriculum of most schoolboys hitherto. But it is at present more urgent to insist that the competitive idea, in our present sports and physical exercises for young people of both sexes, requires very severe pruning.

Conditions Under Which Vigorous Sports May Become Harmful

We are not here speaking of games, but of athletic exercises and competitions and displays. The risks, then, which are more conspicuous in such athletic exercises as long-distance running, or quarter-mile racing for growing boys (whose sprints should never exceed, say, seventy yards), may also extend even to quite desirable games if certain precautions are not taken. There is a definite risk in "mixed hockey," or any game where girls are seriously urged to measure their physique against that of boys. Very often the girls exhaust themselves, often at just the ages which require most sedulous protection from any such risk. Just the same warning applies to the rash mixing up of younger and older children, of either sex, in hard-played games, where the weaker children are often liable to suffer.

Another point must be mentioned where the writer can claim long experience. It is an absurdity that children of either sex, when playing grown-up games, should be expected to imitate the conditions which suit strong men in their middle or late twenties. If twenty-two yards for the pitch, and a certain number of ounces for the ball, are right for adult bowlers, it is egregious that a youngster of thirteen should be expected to bowl the same distance with a ball of the same weight. Most certainly, those who look after the games of our young people should use their brains in order to adapt the conditions to the circumstances. A rather lighter ball, not quite so tightly packed, and therefore not so hard, and a pitch of even as little as eighteen or nineteen yards for small cricketers, will improve the game for them and be much safer.

The Strange Lack of Reason of the Middle-Aged Man

Similarly, in games like hockey and football, the periods of play should always be many minutes shorter than those prescribed for adults, and the area of the playing-ground should always be much smaller. These points are simple and reasonable enough, but one has constantly seen them neglected, partly, perhaps, because the young people prefer to be treated as if they were grown up, but chiefly because so little thought is put into these matters by those who have the responsibility, in reality very heavy, of seeing that youthful exercise shall do the maximum amount of good and the minimum of harm.

As regards the adult's regulation of his own exercise, medical men are only too familiar with the carelessness and strange lack of reason which so often bring disaster in their train, above all to the muscular tissue of the heart. If we define as violent exercise that which causes us to become out of breath—an intensity which, of course, varies with the individual—then we must further note that violent exercise, thus defined, always means that serious, though not necessarily excessive, demands are being made upon the muscular tissues of the right ventricle of the heart. It is always the right ventricle that bears the brunt of exercise, having large quantities of

blood poured into it, and being required to force them, at a great pace, through the lungs for the oxygen which the tissues are so rapidly using up; and the wall of the right ventricle is relatively thin.

By no means are we to fear all exercise that makes us out of breath, and thus demands much of the right ventricle; only we should know what we are doing. So long as the ventricle, inevitably stretched by its efforts, will return to its normal size in a few hours, we need not fear, but the exercise which produces dilatation not so quickly and completely recovered from is a very dangerous business indeed. Tapping the chest, or throwing Röntgen rays through it, will readily demonstrate that, when a schoolboy runs a hard quarter of a mile, and when even a trained athlete does his utmost at such a distance, the right ventricle dilates, under the pressure within it, to such an extent as an inch or more; and it may often be twenty-four hours before it resumes its normal size.

There are two ways in which the heart responds to excessive exercise. In some cases it enlarges in response to the need, and certainly that "compensatory hypertrophy" is the best that it can do. But though such hypertrophy, in the case of an ordinary muscle, involves no risks, in the case of the heart it is always a source of future danger, however necessary it may be at the time.

The Muscle that Matters Most and is Most Ill-Used

The blood-supply of the heart-wall is inexorably limited by the calibre of the arteries which supply it, and the last state of hypertrophy of the heart is inevitably fatty degeneration of the overgrown muscle. Sooner or later the fatty heart must yield to the pressure within it, for fat cannot contract, and is not elastic. In the second group of cases, the heart does not begin by making the response of hypertrophy to over-exercise, but dilates at once, and remains dilated. Such an over-stretched heart is necessarily inefficient in one way or another, for mechanical reasons. This is the kind of heart with which, too often, a man returns home after a holiday which he has devoted to what he thought to be "healthy exercise." Having nicely adapted his heart, during eleven months in the year, to the extremely modest requirements involved in a little quiet walking and much sitting in a chair, he devotes himself during the remaining month to various athletic feats ingenuously designed to set him up for the coming year. But not infrequently the greater part of the coming year is spent in slowly and painfully coaxing the heart, thus overstrained, to return to its natural size.

Mere overstraining, or temporary over-development, of the muscles of the limbs matters little, and even damage done to joints usually matters little more, but damage done to a vital organ like the heart is vitally important. Few of us would run such risks if ever we had had the chance, by means of the Röntgen rays, of seeing the actual beating of an overtaxed heart, and realising that that is what happens when we indulge in over-exercise that we had thought to be merely of the limbs alone. Many a man is killed by running to catch a train who would have been saved by such a warning as this.

The Complicated Joint that is Most Subject to Strain

The knee-joint, particularly, is liable to serious trouble from over-exercise, and especially from football. This is the largest and most complicated joint in the body, and it is very easily injured when it is subjected to certain forms of strain. Often it is the "internal semilunar cartilage" of the joint that becomes displaced, and in many instances nothing but surgical removal will relieve the patient's disability. True, natural movement of this joint, as in walking or running, for which it is adapted, is not to be feared, only oblique and sidelong strains such as occur in football and certain kinds of jumping. Anyone whose joints and bones are constructed lightly and delicately should avoid such risks.

Now, if the foregoing arguments and the doctrine of the "new asceticism," discussed in the preceding chapter, mean anything, they certainly unite in condemnation of the latest, or nearly the latest, of fashionable religions, to which we have given the name of the "Cult of Muscle," and with which we must now finally deal, for it is perhaps the very worst illustration of exercise of the wrong kind.

The Muscle-Making Craze an Exercise of the Wrong Kind

By the cult of muscle we mean simply the modern craze which teaches, in effect, that there is nothing great in man but muscle; that to be a good animal is everything; and that we must develop every muscle to the utmost, even though it be palpably a relic from some period when our ancestors grasped the boughs of trees with their feet, or used their mothers' tails as towing-ropes. No serious student of

anatomy could listen to such nonsense, for the study of the muscular system of the human body shows at once that it has many and widely distributed survivals, which are now in a stage of decadence or retrogressive evolution, and should be allowed to decline accordingly. They have nothing to do with what is now the natural habitat of man, nor with his ordinary habits. They do not even serve him if he wishes to excel in games, for his games, as we shall see, are based upon the specially human characteristics of skill and co-ordination, and not upon the high development of any special muscles or groups of muscles.

The Exploitation of Muscle-Making as a Paying Business

But the cult of muscle, like cults in general, is highly profitable to its chief priests, who include some very enterprising and skilful men of business. Thus, when an outcry was raised in this country some nine years ago, regarding the physical state of the people, in consequence of the revelations of recruiting for the Boer War, and a report was issued upon the condition of the schoolchildren of Scotland in reference to the need for physical training, one of these advocates issued a copy of the report printed in double columns, so that his remarks might be placed opposite each of its conclusions, and his panacea—need we say?—was physical training. The theory apparently is that, having killed many babies outright by compelling them to eat poison, drink poison, and breathe poison, and having administered similar nourishment to the survivors, defying for years together the most elementary and cardinal principles of ventilation, cleanliness, and diet, you may make good the damage by muscular exercise—even to the extent, presumably, of straightening rickety bones and replacing lost teeth.

How Science and Our Feeling of Fitness Alike Condemn Artificial Exercises

It is deplorable to find how many people accept the cult of muscle in this preposterous fashion. Whether or not a spiritual paradise may be won by a deathbed repentance after years of evil-doing, certainly a physical paradise is not to be won by a belated and disproportionate and spasmodic attention to one of the minor laws of health, after the most important years have been spent in defiance of the primal and unescapable laws of man's physical being.

We have already seen that this cult of muscle is condemned by the study of evolution, which clearly shows that the human body is not constructed and adapted in all, or nearly all, of its physical characteristics for the life which man now leads upon the ground. Man's adaptation to his environment is chiefly nervous and mental. His body contains numerous and important "disharmonies," as Professor Metchnikoff has taught us to call them, between his physical constitution and his present vital needs. If we were to deny evolution, and assume that man's body was specially created for his present mode of life, then we might reasonably assume it to be our duty to develop every structure and tissue to its utmost; but with the disappearance of that belief, and the substitution of the belief that man's body is a heritage, in the main, from a prehuman stage in the progress of life, the philosophical warrant for the cult of muscle, even as it was argued, much more moderately, by the Greeks, falls to the ground.

The physiological argument is no less important, but very few laymen are aware of it. It has been shown elsewhere that the voluntary muscles are really the end-organs of certain kinds of nerves called motor, existing for the execution of *purposes*, and it follows that the muscles for which the nervous system and the will have to-day no purpose are simply a burden.

The Demands that Muscle-Making Imposes on the Various Vital Organs

This single consideration gives us a very useful, practical criterion at once. Whenever we are asked to perform special and, as they feel to us, unnatural exercises for the development of certain groups of muscles, we may know at once that there is something wrong.

The modes of exercise which could not possibly effect any purpose, but simply contort the body, or practise one isolated part of it, as if it were a machine, are self-condemned. Either they are developing muscles which are not worth having, or else they are effecting a disproportionate development of some part of the body at the expense of the rest, and of the purposes of the whole.

The importance of physiological expense and economy is practically ignored by everyone in this connection. A muscle is a living organ of great inherent vitality, whether it exists for a useful purpose or for none. It consists of very active living protoplasm, highly unstable, and needing a generous measure of nutriment. A healthy muscle, in a state of "tone," is always consuming food, and producing waste products, in proportion to its bulk. The

highly muscular man, developed by one of the modern systems, requires much food, and throws a heavy burden upon his digestive and excretory organs. Thus even the question of monetary expenditure is involved, but that is the least of it. If muscles are to be maintained at their largest, they must be constantly exercised; and not only does this mean a higher demand upon the organs of digestion and excretion, but, as we have seen, it involves the poisoning of the brain, as well as the rest of the body, by the fatigue-products of muscular exertion. Thus the brain has to pay a double price for the devotion of the bodily resources to the muscles. Large meals involve a large blood-supply to the stomach and the rest of the alimentary canal. This always means the relative starvation of the brain, and shows itself, after a meal, in the torpid or sleepy condition of most large eaters, or of a smaller eater whose blood-supply is not quite adequate.

A considerable degree of relative starvation of the brain must therefore be added to the temporary and slight but very effective poisonings of it by fatigue-products in the case of the man who lives for his muscles.

The Insight and Forethought of Herbert Spencer on Physical Training

All this requires to be remembered; for modern scientific research, notably that of Mosso, already referred to, entirely confirms the insight and judgment of Herbert Spencer, who discussed this question more than half a century ago, and said:

"Nature is a strict accountant; and if you demand of her in one direction more than she is prepared to lay out, she balances the account by making a deduction elsewhere. . . . Let it never be forgotten that the amount of vital energy which the body at any moment possesses is limited; and that, being limited, it is impossible to get from it more than a fixed quantity of results. . . . Everyone knows, for instance, that the digestion of a heavy meal makes such a demand upon the system as to produce lassitude of mind and body, frequently ending in sleep. Everyone knows, too, that excess of bodily exercise diminishes the power of thought; that the temporary prostration following any sudden exertion, or the fatigue produced by a thirty-miles walk, is accompanied by a disinclination to mental effort; that, after a month's pedestrian tour, the mental inertia is such that some days are required to overcome it; and that in peasants who spend their lives in muscular labour the activity of mind is very small. Again, it is a familiar truth that during those fits of rapid growth which sometimes occur in childhood, the great abstraction of energy is shown in an attendant prostration, bodily and mental."

All that modern physiology, a product of the last half-century, or less, can say in comment upon the above passage is that we can now in some degree identify the intimate processes which produce these well observed and stated results. The value of exercise, then, is not at all that it makes us muscularly stronger, with the consequent necessity of having to devote a higher proportion of our vital energy to the muscular upkeep.

The Relation Between Over-Eating and the Need for Exercise

Exercise is valuable for other purposes; and in our discussion of the various right and valuable forms of exercise we must keep those other purposes in view. Here, also, most popular notions are very far from the truth. Few men who grumble at the necessity of taking much exercise, or who simply decline to spend their time upon exercise, however urgently it is ordered, will realise that the special and sufficient reason why they need so much exercise is that they persistently eat too much. So long as they do so, they must take much exercise, which, at least in part, neutralises the effects of their indulgences. But all that is obviously a reason and a function for exercise which should not exist at all.

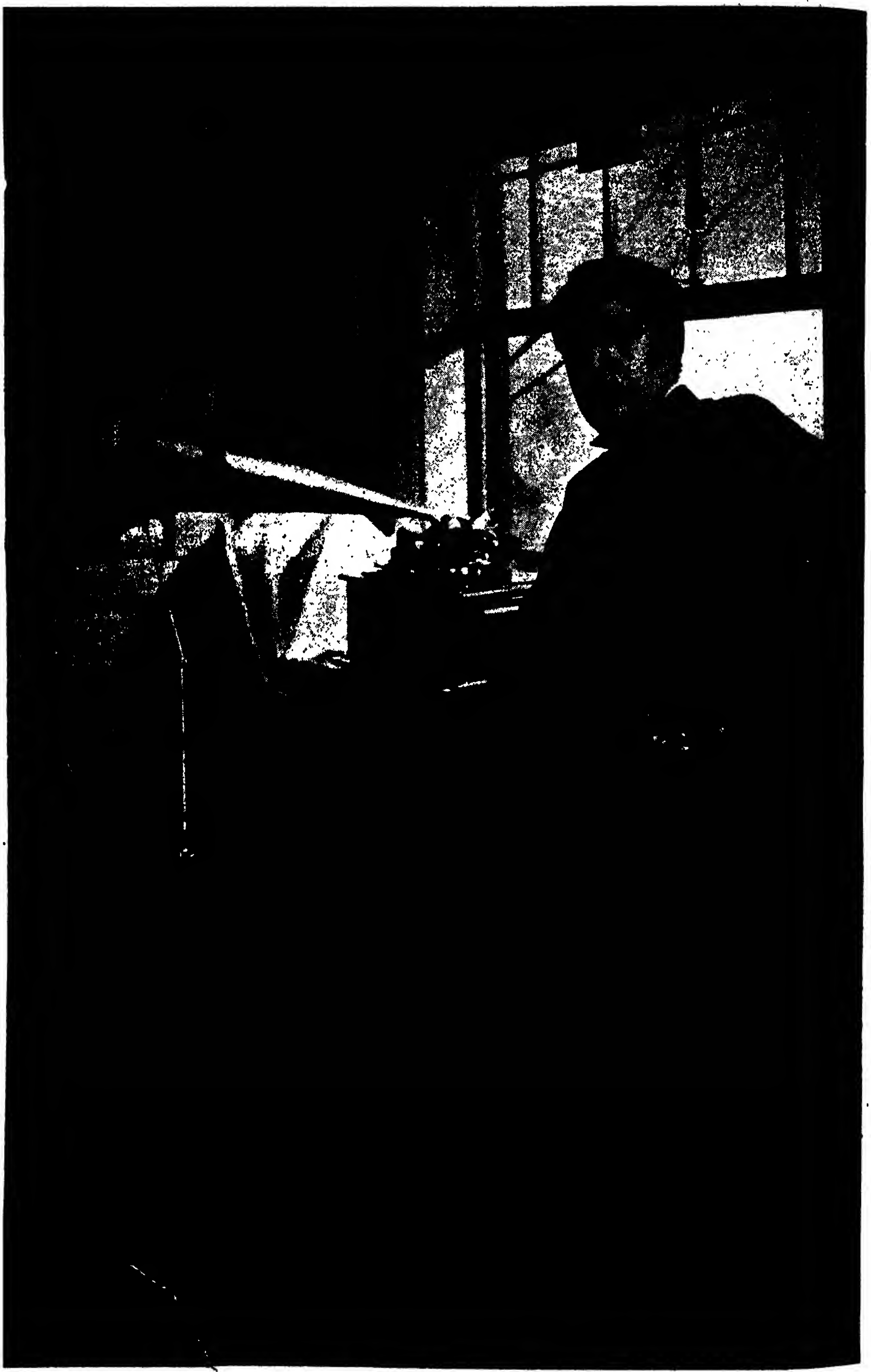
And, again, it is a delusion that exercise, and high muscular development, make us resistant or "strong" in all directions. That is the old and familiar error of confounding muscularity with vitality.

The Familiar Confusion Between Muscularity and Vitality

The two things are utterly different, as we realise when we compare the relative resistance of the two sexes to starvation, hæmorrhage, poisoning, or cold.

Further, we have lately learnt that "training" really means the acquirement of immunity to fatigue. But all immunity to toxins is specific; vaccination only protects against smallpox, not against mumps or chicken-pox, and so on. Similarly, one may become immune to the fatigue-toxin, but helpless before others. A slender but vital young woman called at the physical training institute to consult the Colossus-Apollo who gave oracles within, but, unfortunately, he was "in bed with one of 'is narsty colds"!

THOMAS EDISON IN HIS WORKSHOP



THE GREATEST AMERICAN MECHANICAL INVENTOR THINKING OUT GRAMOPHONE IMPROVEMENTS

1800

MACHINES THAT TALK

Photographs that Sing and Speak and Play Music when a Ray of Light Shines on Them

SPEECH REPRODUCED BY STEEL WIRE

Some years ago an American lad was anxious to become an expert telegraph operator. He was engaged at a small wage to work in a telegraph office at Indianapolis in the daytime, but he was so keen to succeed that his day's work did not content him. It was at night-time, when the line was being used for newspaper work, that speed in receiving messages was most necessary; and the lad reckoned that if he could get some of this nightwork to do the practice would make him an expert, and enable him soon to earn a larger salary. The regular night operator was a man who often took more drink than was good for him, and he was very glad when the boy offered to help him. So, while he was sleeping off the effects of his potations, the lad did his work for him. The ambitious youngster, however, was not by himself equal to the task, but he inspired another lad in the office with his desire to become an expert operator, and by working together they soon managed to get along fairly well. They each sat down for ten minutes at the instrument, and transcribed as much of the report as they could, and carried the rest in their memory. While one was writing out, the other was taking down.

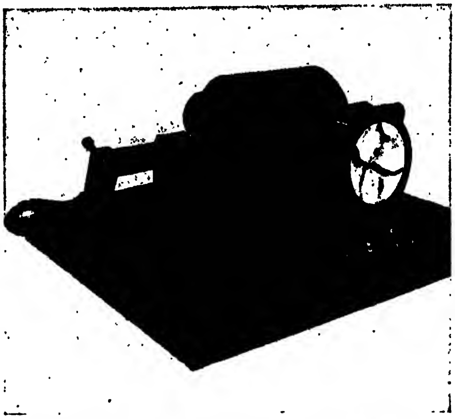
This plan worked sufficiently well until a new man was put on at the Cincinnati end of the line. But he was one of the quickest dispatchers in America, and the two lads found that it was hopeless to attempt to keep up with him. Yet the boy who had first resolved to become an expert operator did not mean to lose his chance of success without a struggle. His name was Thomas Alva Edison; and the difficulty into which he had got himself spurred him on to devise the first of his inventions. Necessity was certainly the mother of it.

He obtained two old Morse registers, and made out of them a kind of tape machine. A strip of paper was run through the first receiving instrument, and as fast as the dots and dashes came from the Cincinnati dispatcher they were printed in indentations on the paper. The paper was then run through the second instrument at the slow speed at which the two lads were able to work. So the messages would come in on one instrument at the rate of forty words a minute, and the two boys would grind them out of the other register at the easy speed of twenty-five. Mighty proud were the youngsters of their achievement. Their copy became so clean and beautiful that they hung it up on exhibition. The manager of the office used to come and gaze at it silently with a puzzled expression. His two infant progenies, it seemed, were more than a match for the swiftest dispatcher in the States. He could not understand it; neither could any of the other operators. For the lads used to drag off their automatic recorder and hide it when their work was done.

But one night they could not keep up with their task. The election of a President was in progress, and copy kept pouring in at the top rate of speed, and the young operators fell two hours behind with their work of transcription. The newspapers sent in frantic complaints, an investigation was made, and Edison's little secret was discovered. He was not allowed to use his automatic recorder any more.

But he kept his machine for converting telegraph clicks into printed marks and changing these marks again into sounds. He went on improving the instrument, and by 1877 it was fairly perfect. It recorded telegrams by indenting a strip of paper with dots and dashes, and it repeated messages any number of times at any rate of speed required. Edison was then experimenting with the telephone, and working

out improvements on Graham Bell's ideas. His mind was filled with theories of sound vibrations, and their transmission by drumlike membranes. Suddenly an idea occurred to him. If indentations on paper can be made to reproduce the click of the telegraph instrument, why cannot the vibrations of a membrane, like that of the human ear, also be recorded and reproduced? That was the question he asked himself. Hastily rigging up an instrument, he pulled a strip of paper through it, and shouted "Hallo!" He then pulled the paper through again, and listened breathlessly. A distinct sound was heard, which a strong imagination might have translated into the original "Hallo!" Edison was certain he had found the talking-machine. But a friend named Batchelor, who had witnessed the experiment, was very sceptical, and bet him a barrel of apples he couldn't make the thing go. Now, Edison was very fond of apples. Down he sat, and made a drawing of a model, and took it to a man who was working for him.



EDISON'S FIRST TINFOIL PHONOGRAPH

"Here is a four-dollar job for you," said the inventor. "It's a machine that talks."

The workman grinned, thinking it was only Mr. Edison's little joke, but, wild with enthusiasm, the inventor told him to hurry with the work, and the model was soon ready. Edison arranged some tinfoil on it, and spoke into the mouthpiece. The workman looked on, and he was still grinning.

"But when I arranged the machine for transmission," said Edison, thirteen years afterwards, "we both heard a distinct sound from it, and he nearly fell down in his fright. I was a little scared myself, I must admit. But I won that barrel of apples from Batchelor, though, and I was mighty glad to get it."

EDISON SPEAKING INTO THE PHONOGRAPH IN 1888

Though to Edison must be given all the credit for making the first practical talking-machine, yet it is clear that he owed a great deal indirectly to Graham Bell's invention of the telephone. Moreover, his phonograph was a direct adaptation of the phonautograph, an instrument for writing sounds, invented in 1856 by Leon Scott. Edison is the father of the talking-machine, but Scott is certainly its grandfather. Scott's phonautograph resembled the phonograph in both its name and in its structure. It consisted of a speaking-horn, shaped like a small barrel, and made of plaster. The upper end was left open to receive sounds, and the lower end was fitted with a short brass tube about four inches in diameter. Over the end of the tube a flexible membrane was fixed, like the parchment head of a drum. Then on the outside of the membrane was fastened, with a little glue, a hog's bristle, which acted as a stylus or pen. Just in front of the bristle, and within reach of it, was a cylinder covered with lampblack paper. The cylinder was turned by means of a handle, and as it turned round it also moved forward in answer to a screw-thread cut on the axle on which it spun.

This instrument is practically identical in principle with Edison's original phonograph, except that the American inventor

used tinfoil instead of lampblack paper, and attached to the membrane of his machine a steel needle instead of a hog's bristle. In both cases the membrane vibrated under the influence of sound-waves made in the air by the human voice. As the membrane vibrated, the stylus fixed to its outer side began to write on the material attached to the cylinder. This sound-writing consisted of wavelike lines, the shape of the waves varying with the nature of the sound.

The wave-lines in Edison's machine, however, formed indentations on the tinfoil. It was here that the American inventor's voice. First, it vibrates to the air-waves of sound, and transmits them, by means of its stylus, to the tinfoil. Then it vibrates in obedience to the up and down motion of the stylus along the indented lines of the tinfoil. So by a much simpler mechanism than that contained in the human throat and mouth it makes all the articulate sounds of speech and song.

Marvellous as were the first talking-machines that Edison devised, they were scientific curiosities rather than instruments of use and beauty. The reproduced sounds were distressingly "tinny" and unmusical. It was difficult to remove the

LISTENING TO THE FIRST PHONOGRAM SENT BY MR. EDISON TO ENGLAND IN THE YEAR 1888

experiments with his automatic telegraph-recorder were of vast importance. His phonograph was not merely a sound-writer; it was a sound-maker. For when the little steel pen began to travel again over the indentations it had made in the tinfoil, it caused the membrane to vibrate in response to its movements, just as the membrane of a telephone receiver vibrates in answer to the electric current set up by human speech at the other end of the wire. As the membrane vibrated it made waves in the air, and these waves were sound-waves. So the machine talked. In other words, the membrane of a phonograph does the work first of the human ear and then of the human

tinfoil from the cylinder or to replace it without distorting the material and injuring the indentations. So it was necessary to have a separate cylinder and screw and crank for every new record. Moreover, the motion given to the cylinder by turning a handle was not regular. Sometimes it was quicker than usual, and sometimes it was slower. Now, the pace at which the membrane is vibrated has an important effect on the quality of the sound. Too high a speed makes the note sharp, too slow a speed makes its flat; and both make it very unmusical, and false and distorted.

Owing to these defects, Edison lost interest in his invention. He was very busy

at the time in improving the telephone and in working out the details of his electric lamp. Graham Bell, the inventor of the telephone, however, saw what possibilities lay in the talking toy that his rival had grown tired of. Assisted by his brother, Chichester Bell, and by C. S. Tainter, the father of the telephone developed and improved the crude ideas of Edison, and produced a machine called a graphophone. In this instrument clockwork was used instead of hand motion, and the record and reproduction of sounds were very much improved. Instead of the tinfoil, there was employed a thin mixture of wax on light paper cylinders, and the new machine was much more handy and effective than the old phonograph.

Three Inventors' Race against Each Other to Produce a Popular Talking-Machine

But as soon as Edison had some time to spare he also began to improve upon his original ideas, and he produced the modern phonograph of commerce. In this a special wax cylinder is used. The record is cut by means of a tiny agate or sapphire point, which makes minute depressions in the wax. The reproducing point is also of agate. It passes over the indentations and communicates its movements to the membrane by means of a delicate combination of weights and levers.

In the phonograph and all its varieties, the record in the wax is formed of a series of little hills and dales, running round and round the cylinder. Thus the sound-waves are represented by actual waves in the wax, each wave sloping upward and downward like the rippled surface of the sea. When in 1886 Graham Bell and his partners patented their graphophone, they kept to what is now known as the "hill and dale" groove.. But another inventor, Emile Berliner, who had been working on a new device in connection with the telephone, saw that both kinds of talking-machines then existing had a common defect.

The Way in which Waves of Sound are Transformed into Waves of Wax

Berliner had already done much to improve the telephone, over which Edison and Bell had been fighting; and in 1887 he again stepped between the two rivals who were struggling over the talking-machine. He carried the prize away from both of them by inventing the gramophone.

Externally the chief difference between a gramophone and a phonograph is that the gramophone records are much handier in shape. Consisting of thin, flat discs, they occupy much less room than the cylinder records of the older machines. Moreover, the mechanism by which the gramophone is driven is simpler. A single movement of a turntable spins the disc around and works the instrument. In the phonograph, on the other hand, there are two movements. First the cylinder has to be turned round; then, while it is turning, a secondary motion has to be imparted to the pen and the membrane that travel with a sideways movement over the revolving cylinder. This secondary motion, by means of a separate feed-screw, is not needed in the gramophone; hence the simplicity of the newer machine.

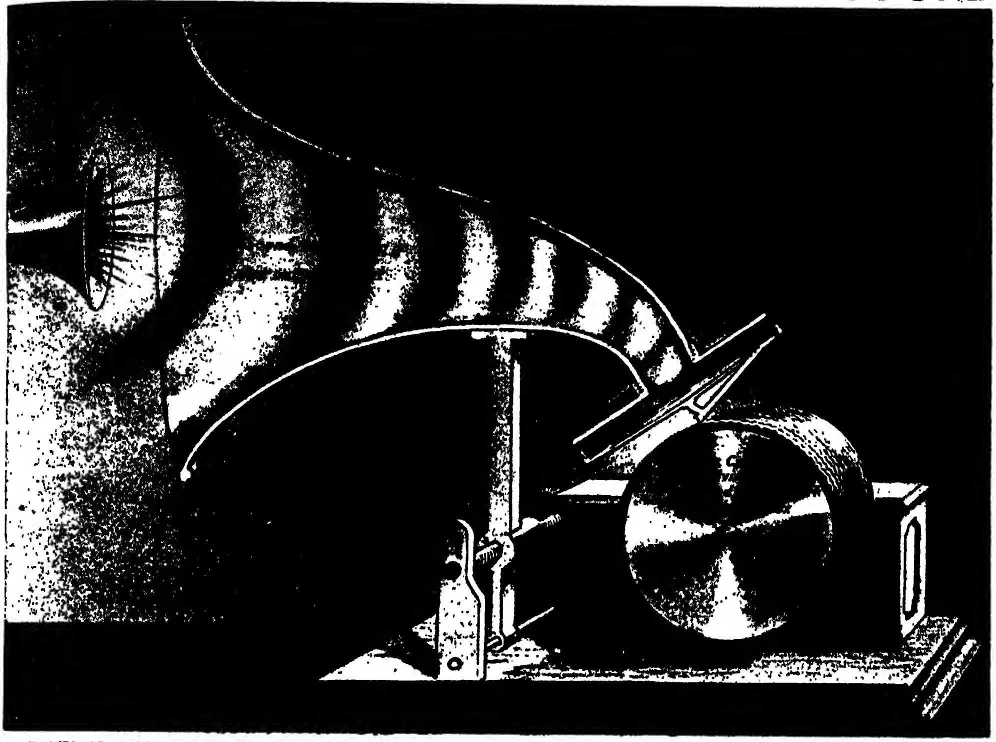
But the grand difference between the gramophone and the older instruments lies in the manner in which waves of sound are translated into waves of wax. Mr. Berliner saw that both Edison and Graham Bell were at fault in adopting the "hill and dale" method of recording sound. For the needle often jumped from the top of one hill to another, and missed the dales. The result was that a noise was produced instead of a sound. This jumpiness seriously interfered with the use and beauty of all talking-machines; and it is the chief merit of Mr. Berliner that he completely avoided it by inventing something quite different from the hill and dale cut. In the Berliner cut, used in the gramophone, the depth of the grooves in the record is always the same.

How British Enterprise made the Gramophone Industry a World-Wide Business

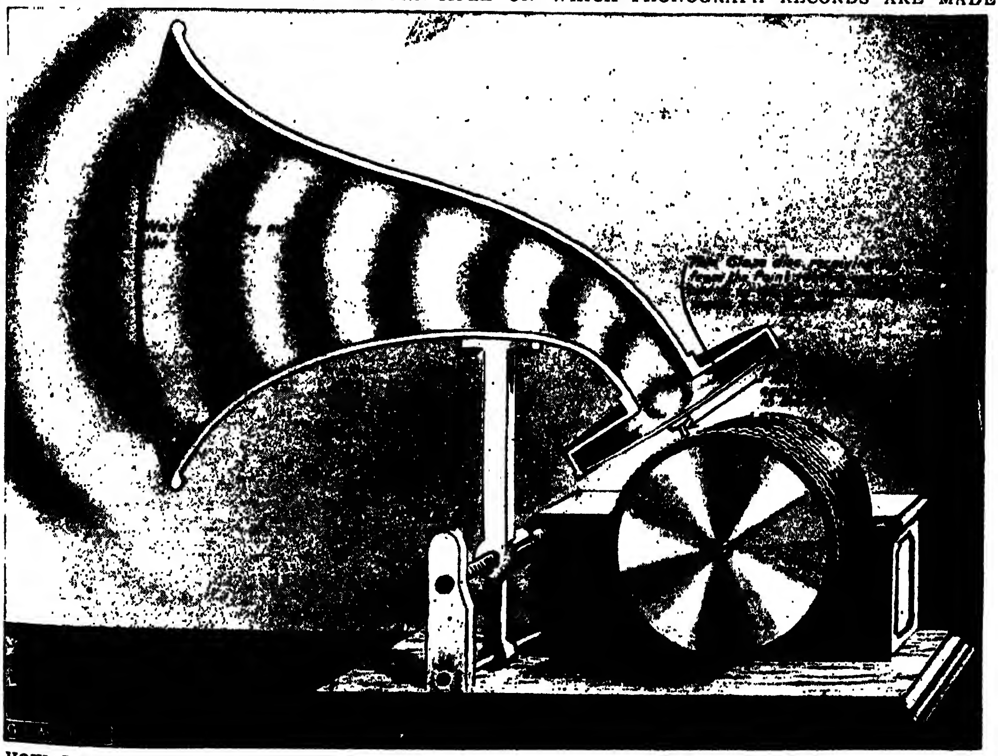
The floor of the tiny lane running round and round the flat disc is absolutely level, and the waves are cut out of the sides of the two minute walls. So, instead of the needle having an up and down movement, it works forward from side to side.

Simple the improvement seems, but the practical advantages of it are of very great importance. Not only does the Berliner cut make the best gramophones steadier and clearer than the machines in which the waves run in hills and dales, but the records themselves wear much better. The point of the reproducing needle of a good gramophone merely glides in and out of the little walls in the disc, and does not injure the material. The needles are not pointed with a hard fragment of agate or sapphire; they are merely made of mild steel. They take the wear, but, as they only cost about sixpence for two hundred, the expense is exceedingly slight.

Thus it is not surprising that the instrument invented by Mr. Berliner should now be the most popular of all talking-machines.



A PICTURE-DIAGRAM SHOWING THE PRINCIPLE ON WHICH PHONOGRAPH RECORDS ARE MADE



HOW THE PHONOGRAPH GIVES BACK AS SOUND-WAVES THE IMPRESSIONS ON THE CYLINDER

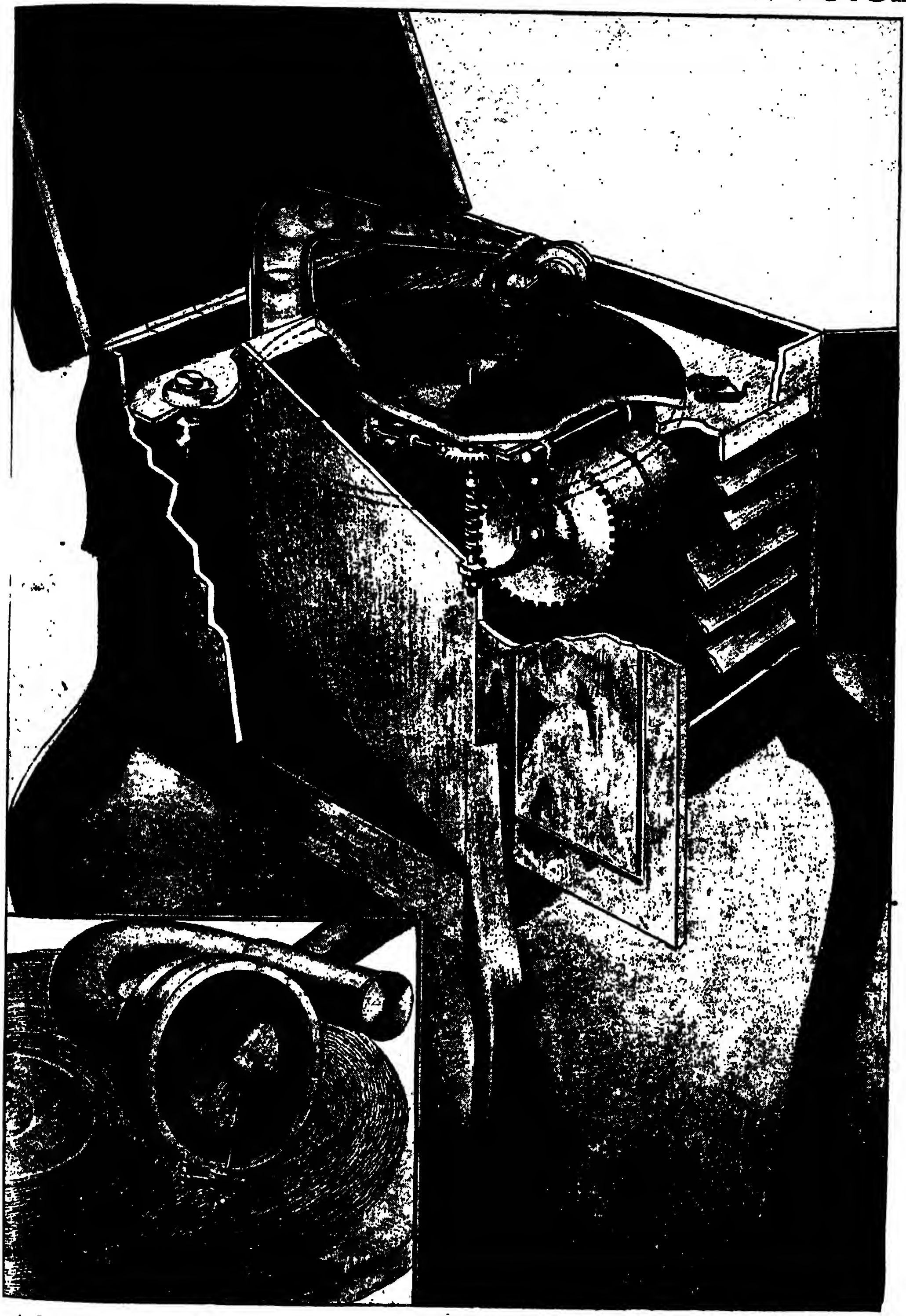
And it is a matter for gratification to find that British enterprise is the force behind the most successful of the wonderful instruments that have become a factor of general value in modern civilisation.

Possessing in the famous picture of "His Master's Voice" the most effective advertisement and trade-mark ever invented, the original Gramophone Company has become in a few years a British industry of enormous size. It is probably the third largest business concern in the entire world—excluding firms like the American Steel Trust, which owe their size to the fact that they are combinations of industries, instead of being a single organisation. The managers who direct the great company whose factories cover many acres of ground at Hayes, in Middlesex, and gives work to thousands of people, must be congratulated upon the courage and ability that have enabled them to develop Mr. Berliner's invention into one of the most important of British businesses.

Unfortunately, it was recently decided in a court of law that the word "gramophone" was not the property of the company, and that it could be used by any makers of talking-machines. The original company has therefore to build now upon its trade-mark, "His Master's Voice." Yet it will be very difficult for any foreign manufacturer to disturb by cheap and ineffective imitations the vast industry which is centred at Hayes. The original Gramophone Company does not rely now even upon its Berliner patents. For so many striking improvements have lately been made to the instrument that Emile Berliner himself would scarcely recognise it. There is, for instance, a secret process of manufacturing the hard, black records, with which no one but the manager and a few trusted assistants are acquainted. Even the working people cannot discover the secret, for they only perform that part of the labour which is already covered by recent patents.

TESTING RECORDS IN A PHONOGRAPH FACTORY

A good gramophone must always cost at least as much as a first-rate watch. For concealed in the box beneath the turntable is one of the most exquisite and delicately balanced pieces of mechanism in general use. The turntable has to be revolved with extraordinary precision and regularity. The slightest change in speed alters the pitch of the sound, and makes false notes and discordant noises. On the other hand, the motive power is obtained merely by winding up a spring and letting it unwind



A PICTURE-DIAGRAM SHOWING THE MECHANISM OF A MODERN TYPE OF GRAMOPHONE

itself. A spring is much more convenient and much cheaper than an electric motor, such as Edison uses in some of his machines. But the trouble with a spring is that it is very irregular in action. It begins with a slow movement, and when it is nearly unwound it goes sharply and swiftly. This change in its speed is utterly destructive of all the fine qualities of a gramophone. So the movement of the spring has to be regulated and distributed by a series of ingenious devices, made and fixed with the utmost skill and care.

Practically the only defect which the gramophone now has in common with other talking-machines is the slight hissing and grating noise sometimes produced by the needle on the surface of the record. But some experiments made some months ago prove that this slight defect can be removed. The friction noises are quite separate and distinct from the musical tone, so that the listener can train himself to hear one without hearing the other. Thus it seems that in the ear there is a mechanism for detecting noises of high pitch, as distinct from ordinary musical sounds. A Scottish man of science, Dr. John D. M'Kendrick, has noticed this, and discovered a very curious means of filtering the noise of the needle from the sound-waves produced by the vibrating membrane. It occurred to him that by making the sounds pass through numerous narrow channels, the noises created by short waves of high pitch might be damped off, while the longer waves of musical tone could travel through the channels unaltered, except for a little loss of energy from friction.

He fitted a tin tube between the horn and the hollow arm conveying the sounds from the membrane. The tin tube was then filled with a mixture of hard peas and beans wrinkled by age or drying. The wrinkled surfaces formed a maze of narrow passages, and the short waves of high-pitched noises wandered about these passages until they died away. So only the long waves of musical sound issued from the simple but strange filter. It is true that the musical tones also lost some of their brilliancy, but they were purer in quality and more natural.

MAKING A BAND RECORD IN A GRAMOPHONE FACTORY

Other substances were then tried—glass balls, marbles, small fir-cones, gravel, and shreds of tin, but the best effect was obtained with wrinkled peas.

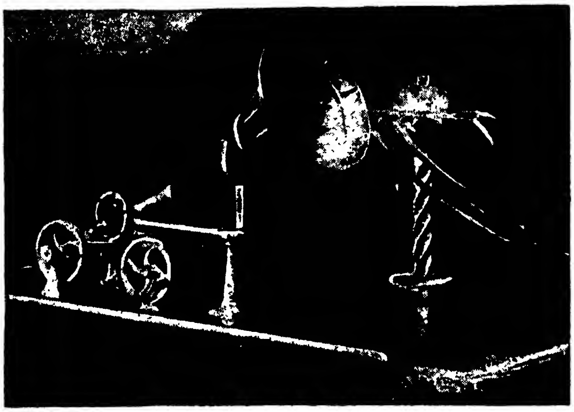
Dr. M'Kendrick then began to search for some means of restoring to the true musical tones the brilliancy they had lost in their passage through the filter. Here

THE MANUFACTURE OF THE GRAMOPHONE

THE FITTING UP OF GRAMOPHONES OF ALL STYLES IN A GREAT FACTORY

GIRL-WORKERS POLISHING RECORDS IN AN UP-TO-DATE GRAMOPHONE FACTORY
These photographs of their factory are by courtesy of the Gramophone Company

he was helped by Mr. Ernest de la Rue, who found that by filling a zinc tube with pieces of corrugated zinc the long sound-waves were made very brilliant. So, in the latest form of filter, zinc fragments are mixed with dried peas and beans, and the result is excellent. All the noise of the needle against the sides of the walls of the record is caught and held by the filter, but the musical tones of the human voice and piano and orchestra issue clear and beautiful and brilliant.


ONE OF THE EARLIEST GRAMOPHONES

One of the great advantages of the filter is that it enables one to listen to pure music in a small room. A voice that sounds harsh in the ordinary way becomes sweet and mellow when reproduced on a gramophone with a filter. Harshness of tone is produced by over-tones of high pitch that mingle with the long, clear waves of sound coming from a singer's throat. There are very few persons who do not need to undergo a long course of voice production in order to learn how to form singing sounds free from high-pitched over-tones. But now the voices of even untrained singers would be sweetened and clarified when reproduced through the filter of a gramophone. Besides, the filter serves to bring out the pure tones of all string instruments. It is marvellous how beautiful the record made by some large orchestra sounds in a small room when the complex and intricate mass of sound-waves is passed through some dried peas and bits of zinc. The music is soft and yet full, clear and yet not overpowering, and as delicately brilliant as the notes a lark pours down as he circles between earth and heaven.


A MODERN TRUMPET GRAMOPHONE

It is a very remarkable thing that so simple an appliance as a membrane vibrated by the movements of a needle running between two walls of wax should be able to produce the voice of the greatest of singers or the music of the most famous of orchestras. Some sort of vibrating membrane will always be used in these wonderful machines, though it is possible that improvements will be made in the substances employed for the purpose. At present the best results seem to be obtained by a thin sheet of transparent mica. This acts in somewhat the same way as the drum of the human ear. Supposing a considerable number of different orchestral instruments are filling a hall with various kinds of musical sound-waves. These waves do not reach the ear singly. They come in one wave of sound, full of delicate and complex variations, all embroidered, so to speak, on the single general impression. That is to say, the drum of our ear does not first record the music of the high violins, and then register the melody of the second violins, and then go on to note, one after the other, the waves in the air by the horns, bassoons, bass viols, flutes, and other instruments. It simplifies all the effects into one single sound-wave, which is, however, full of exquisite modulations.

The membrane of the gramophone acts in the same way. It reduces a mass of simultaneous sounds to a single composite note. When a curve in the walls of a gramophone record is examined under a powerful microscope, it is seen that there is always a number of minute indentations in the single curve. These delicate marks are observable in all records. Even when a single instrument is used, the sound-wave is not pure. It is accompanied by a train of

MADAME TETRAZZINI SINGING INTO A RECORDING INSTRUMENT FOR FUTURE AGES

smaller ripples of sound. Suppose the same note is sung or played in turn by a man's voice, a violin, a cornet, an organ, a banjo, and a piano. If a gramophone record of all these performances were made, it would be found that the successive notes were recorded in a wavy line. Each wave would be of the same length, but the outlines would differ according to the source of the note. Instead of each wave being a pure curve, it would be jagged, like the teeth of a saw.

A Talking Instrument that Works by Means of Compressed Air

The jags represent the secondary waves of sound, which give a note its special quality, and enable the ear to distinguish by what means it was made. In the case of an orchestral record, the waves in the wax are exceedingly complicated. They are formed by the blending of perhaps fifty large waves, together with a far larger number of secondary waves representing the sound-qualities of the various instruments. Yet all this is recorded in a single jagged curve in the wax, that cannot be distinguished by the eye. And when the steel needle hurries past this tiny rugged curve, it makes the membrane vibrate with such delicate complexity that all the original sound-waves are re-created on the air and sent into the ears of the listeners.

The apparatus is so simple and the result so astonishing that it is doubtful if the gramophone will ever be superseded in popular use by any other kind of talking-machine. Yet a steel needle and a wax record are not the only means of vibrating a membrane, and making it reproduce any kind of sound. A few years ago Sir Charles Parsons, the inventor of the steam turbine, perfected a compressed-air talking-machine. In this instrument, a column of compressed air is controlled by a valve, and the valve is connected with the bar holding the needle.

How a Steel Wire, One Hundredth of an Inch Thick, Speaks by Magnetism

As the needle moves along the record, its vibrations are communicated to the valve. The valve in turn transmits the pulsations to the column of compressed air, which then produces sounds identical with those that originally made the record. This compressed air machine is known as the auxetophone, and it is fitted with a little electric motor which compresses the air.

The instrument is somewhat too expensive when compared with the clockwork gramophone. And the same may be said of Professor Valdemar Poulsen's telegraphone. The telegraphone, however, is the most ingenious thing ever invented by man. It is a miracle. Moreover, there are many men of science who regard it as the talking-machine of the future. Undoubtedly it is rather costly to work at present, but the principle on which it is constructed is so wonderfully strange and original that it is certain to be developed some day into a commercial success. Probably it will first come into use as an addition to the ordinary telephone, but it deserves to stand by itself.

In the telegraphone there is no wax disc or cylinder, and no needle is employed. In their place is a steel wire, only one hundredth of an inch thick. This wire can be full of music or speech or song, and yet nothing is visible on it. The sounds are recorded in invisible electro-magnetic forces which are stored up in the steel wire. An ordinary telephone apparatus is used. The sounds are sent into the mouthpiece of a telephone, and there they are transformed into electrical pulses. The electricity flows along the telephone wire in the ordinary way until it meets the steel wire of the telegraphone.

Changing Speech and Song into Magnetic Force that Comes Back in Sounds

The steel wire unwinds from one reel to another, and in so doing it comes between the poles of a little magnet. Connected with the magnet is the ordinary telephone wire, carrying the current of electricity set up by the musical song or speech. The result is that every electric pulse from the telephone wire makes the magnet active, and the magnet in turn communicates its magnetism to the bit of steel wire passing between its poles.

Thus there is a threefold transformation. The sound-waves are first changed into electrical energy; then the electrical energy is changed into magnetic force, and this magnetic force is communicated to the steel wire one hundredth of an inch thick. When the magnet has worked from one end of the wire to the other, it automatically shifts back to the starting-point, and the machine is then ready to reproduce all the sounds that it has recorded. The instrument is disconnected from the telephone wire, and switched on to an ordinary receiver or ear-piece. The coil of wire is then set in motion, and as it passes the poles of the magnet it gives back its magnetic force, or, rather, it imparts its magnetic force to the magnet. The magnet then acts on the membrane of the receiver, making it vibrate in numerous little attractions and repulsions. These

THE TUNES OF LONG AGO AND FAR AWAY

THE GRAMOPHONE CARRIES ECHOES OF HOME TO THE NATION'S MOST DISTANT OUTPOSTS

vibrations give rise to sound-waves which exactly reproduce the sounds originally made in the mouthpiece of the telephone. The magnetised steel wire, however, does not lose, in this reproductive progress, any of its magnetism. It can repeat its record hundreds of times without any loss of distinctness. On the other hand, the record can at once be obliterated by passing the steel between the poles of a strong magnet. This is usually done by using two electro-magnets. One magnet magnetises the wire in obedience to impulses from the telephone current, while the other magnet effaces the record when necessary.

Extraordinarily ingenious as is the Poulsen instrument, it needs to be improved before it comes into general use. The long steel strips are rather expensive and inconvenient for storage; and at present the electric batteries and the small but complete telephone apparatus also go to make it very costly. Yet the principle of the telegraphone is so brilliant that several other inventors of genius have been attracted to it, and Mr. A. P. Hanson has already worked out another application of the idea. So it is not unlikely that a steel disc, with invisible magnetic record of sound-waves, will become the talking-machine of the future.

VOICES FOR POSTERITY. STORING GRAMOPHONE RECORDS OF FAMOUS SINGERS' VOICES IN THE VAULTS OF THE PARIS OPÉRA

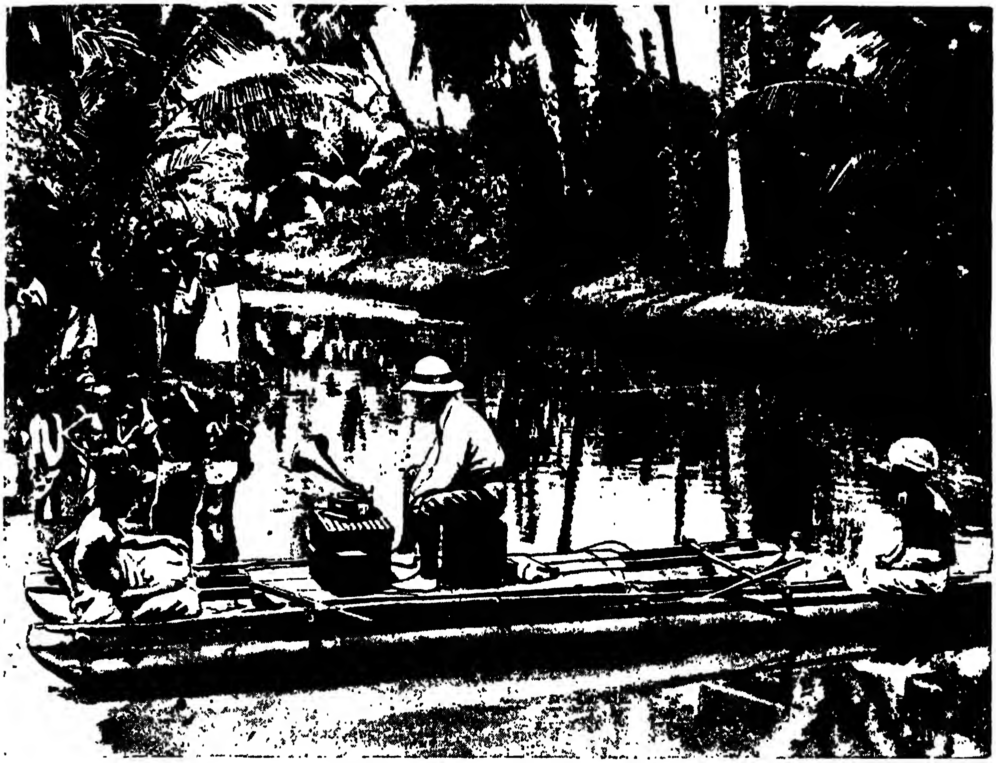
Almost as curious and surprising as the Poulsen machine is the photographophone invented by Professor Ernst Ruhmer. In this instrument an ordinary photographic film is used to record and reproduce the waves of sound. The vibrations of speech or music are made to influence the flame of an electric lamp in such a way that the light varies at every alteration in the pitch or quality of the sound. Behind the lamp is a moving band of photographic film; and when this film is developed in the ordinary way it is found to be covered with dark and bright stripes, indicating the strength of the electric flame at different moments. The developed film forms as admirable a record of speech and music as the waxen cylinders or discs used in ordinary talking-machines.

To change the strips on the film back to the sound that produced them, a very strange substance called selenium is employed. About forty years ago, Mr. May, a young English engineer engaged in laying a submarine cable, discovered that selenium acted in an extraordinary way in the presence of an electric current. It would let the current pass through if there was no light falling on it; but when the selenium was illuminated, it became very resistant to the passage of electric energy. Professor Ruhmer uses a selenium plate connected with an electric circuit and a telephone receiver. The photographic film, with its stripes of light and shade, moves between a lamp and the selenium plate. Thus the light from the lamp is intercepted by the dark portions of the film, and only allowed to affect the selenium plate when the bright stripes occur. The consequence is that the electric current is converted into a series of pulsations corresponding to the lights and shadows on the photographs. The pulsations affect the membrane of the receiver and give rise to sound-waves that answer to the original waves sent into the electric lamp. The selenium plate process is at present more cumbersome than the magnetic process of recording sounds used by Professor Poulsen. Yet it is not improbable that the photographophone will become the most popular of all talking-instruments. For the inventor hopes to develop it into a combination of cinematography and sound reproduction. The selenium plate will be used to reproduce pictures as well as sound. Already a wonderful Electric Eye has been invented by a Russian man of science, in which a selenium plate is employed to

reproduce pictures at a distance, in somewhat the same way as a telegraph reproduces messages at a distance.

Is not all this a marvellous advance on the little, tinfoil machine that Edison vaguely thought of when he was trying to become an expert telegraph operator? At present, no doubt, the talking-machine is chiefly a pleasant form of entertainment and education. It does for the world of music what the invention of printing did for the world of literature. It puts the loveliest and most spiritual of arts within the reach of everybody, and it preserves and immortalises the most fugitive and the most glorious of all the activities of man. Already in the British Museum in London, in the Grand Opera House in Paris, and in public institutions in Austria and Germany the achievements of the great musical artists of the present generation are being recorded for the delight of future generations.

Many explorers of savage lands now take a talking-machine with them, and bring back documents in wax of great value in the study of the languages of the human race. A few months ago, a solitary survivor of a Red Indian tribe of savages was discovered in California. The man was living in a secluded valley, under conditions of life resembling those of the European Stone Age. A forest fire compelled him to flee for life towards the town, and he has now become the principal exhibit in an American Museum of Anthropology. His speech is being studied by a professor, who cannot yet, however, understand clearly what he says. Yet if the savage were to die or disappear to-morrow, the legends of his vanished race would be preserved. For he has been induced to relate them to a talking-machine; and there is now a large stack of records in an unknown language, which the professor hopes some day to be able to interpret. Very likely the talking-machine will soon be introduced into all our schools. It is an admirable instrument for teaching the pronunciation of foreign languages. In fifty years' time no one will write letters. Everybody will possess a cheap talking-machine of the Poulsen type for recording and reproducing speech by electro-magnetism. Already Edison is selling sheets of thin steel at 5s. for 40,000—a price much below that of paper. We wait only for an improvement in an instrument which is known to be practicable.



AN AL FRESCO GRAMOPHONE CONCERT IN THE TROPICS

The Post Office has become softened by a humaner sentiment since it has been the medium of the State's just and kindly recognition of the natural claims of old age.

THE TRIUMPH OF A PENNY

How Man's Speech to Man, by Wire, Wireless, 'Phones, and Letter, has Made the Greatest Enterprise in the Empire

THE INCREDIBLE BUSINESS OF THE POST

The romance of commonplace reality may claim a place alongside the romance born of the imagination, or even the wonder of scientific processes, when its appeal is made through such a triumph of co-ordination and organisation as the British Post Office. That office represents the greatest business enterprise in the British Empire. It is the highest effort in the economy of civic endeavour. Be it admitted that it is fretted with many imperfections and qualifications; that its utility is hampered by inequalities and absurdities. But it moves. In its attempts at progress, it is at times betrayed into reaction, but the net balance of change is for good. Every new reform makes further reforms inevitable. Every new invention in relation to locomotion, to the transmission of speech and thought, to business organisation and management, is, soon or late, reflected in the conduct of this undertaking, which has a nation for its owners, and the whole civilised world as agents or beneficiaries.

The British Post Office is, in a sense, more mistress of the seas than the British Navy, for all the seas are her highways. She links the Motherland not only with the capitals of the continents, but with their remotest hamlets; she carries a message to the loneliest islands in the farthest solitude of distant ocean; she sends her dog-teams towards the Pole, her camels through the desert, her naked porters through primeval forest and malarial swamp; the Equator and the Arctic waste, equally with the lone ocean island, must be served. She ploughs the wildest seas, she crosses the widest waterless wastes, she pierces the heart of the most massive mountain ranges. Ships carry her letters over the seas; cables carry her messages, electrically borne, beneath the seas; and, swifter than the wings of the wind, she sends her wireless greetings speeding through the all-pervading ether. She brings news daily to cheer the solitude of our own peasants at home, remote from the main stream of life in the quiet of our native land; she reaches the pioneer far out in the wilds on the fringes of the Empire. She enables us to exchange messages with friends at sea all the while they are travelling between the Old World and the New. She advises the farmer that storms are coming against which he had need safeguard his cattle and his crops; she sends timely warning to the mariner at sea of a wreck that lies in his track and may endanger the vessel he navigates. She enables us to converse with people in distant places as freely as if they were in the same room with ourselves.

For her service she has steamships and steam-engines, motor-cars and horsed vans, bicycles and tricycles and pneumatic tubes, dog-teams and reindeer-teams, caravans of camels and yaks and lamas and elephants and cattle. At need she may have her aeroplanes and balloons, and winged messengers in the form of the pigeon-post. There is no method of locomotion known to man, no engine of travel, no type of beast of burden, which is not in the service of the British Post Office. The very tides of ocean are called to her aid, and barrels and floating logs, and inflated goatskins, carrying the mails, cast into the sea at St. Kilda, or islands in more distant seas, bring to the mainland or to the great ships' paths the letters which storms prevent the mail steamers from carrying.

But the mails and telegraphs and telephones are only a part of her work. Yearly her mission to mankind is extended. She insures a man's life and pays him, in due season, his annuity; she dispenses their awards to the millions of old-age pensioners who, week by week, present their little

cheque-books at her counters. She has the biggest banking business in the world, carried on at 15,000 branch establishments, with deposits over £170,000,000, the property of ten million customers. She has the biggest carrying business in the Empire, handling every year nearly 122,000,000 packages, with a return, as her share of the fees, of over £1,300,000. She delivers 871 million postcards every year, and 732 million halfpenny packets, in addition to upwards of 196 million newspapers, and over 3000 million letters, or 68 letters yearly to every man, woman, and child in the United Kingdom.

And all the vast machinery of the Post Office may be set in motion by the use of a penny stamp. The humblest among us can obtain a thousandfold greater results from his penny than could have been gained a couple of centuries or so ago by all the king's horses and all the king's men, with the revenue of a kingdom behind them. A penny takes a letter to any part of the world where the British flag flies. It takes it to any part of the United States of America, a continent of which Henry VII. possibly never heard more than a rumour. The penny takes a letter to Australasia, which neither Tudors nor Stuarts knew to exist; to many of the chief cities of China, to Morocco, to Afghanistan, to Arabia, and to remote parts of the Dark Continent, which within the days of the present generation were dark indeed.


THE POST-OFFICE HOME SAFE

Down to the time of Henry VIII., the British postal system existed practically only in time of war. Correspondence was carried on between the Court and the theatre of hostilities by means of messages borne by couriers; and war and the postal system would cease together. But in 1533, Henry, fourteen years before his death, ordered Sir Brian Tuke to set up posts "in all places most convenient." This meant simply that Tuke had to see that horses were kept ready at various points for the use of the couriers carrying the Royal missives. Where such provision was lacking, or where post-horses were not forthcoming within half an hour of the arrival of a Royal messenger, the local magistrates and constables were compelled to seize the first available, and send them on their way. But there was no general or public post; the system was conducted exclusively for the use of the sovereign. The only roads were pack-horse tracks, beaten out upon the original winding paths followed by peasants on foot, who, to avoid swamps, took devious ways over the hills. In many instances we still follow the direction of those tracks, having only improved the surface. But pack-horse tracks were the main roads of England when the British post was beginning; and there was not an attempt at a scientifically made road from the time of the Romans until Telford and Macadam began their work of highway-making in the year of Waterloo.

Bridle-paths had become roads, it is true, for coaches began to run with the mails and passengers in 1784, but the conditions were so vile that vehicles were often embedded in the ruts; they were in danger of toppling over unguarded precipices; they ran through so-called roads which were swamps bounded by mudbanks seven and eight feet in height. But coaches were not dreamed of in the days of which we have been thinking, nor even any regular system of posts. Tuke informed his sovereign that "the King's Grace hath no ordinary posts, nor of many days hath had." There were only four routes—one each to Scotland, via Berwick; to Ireland, via Beaumaris; to the Continent, via Dover; to the Royal Dockyard at Plymouth.

So unimportant was communication between the Government and the Navy that for ten years after the defeat of the Armada Queen Elizabeth dropped the post between London and Plymouth. The posts, as we have seen, were the sovereign's. There were few people to write, still fewer who thought of using the post. Elizabeth decreed that the postal messengers should carry only the letters of the Court; that other letters should be considered of no account, and that no person should induce a Royal messenger to ride with private correspondence. The horses maintained for the postal service were for the Court alone, and the scale of payment was 2½d. per mile for the horse and an allowance to the guide for food, which consisted of a measure of groats. None but postmasters were allowed to keep post-horses or to collect or deliver

THE OLD PACE AND THE NEW

THE MAIL-COACH OF THE OLDEN DAYS CHANGING LETTER-BAGS EN ROUTE

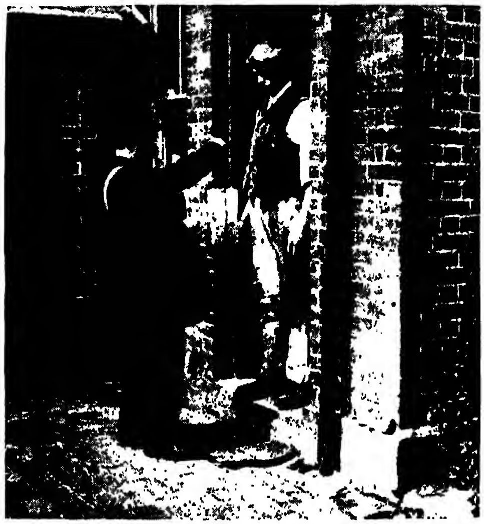
TODAY'S MAIL—THE MOMENT BEFORE AND THE MOMENT AFTER AUTOMATIC EXCHANGE OF BAGS

letters. The fact is, correspondence was viewed with suspicion; the posts were officially regarded as vehicles for the propagation of treason. Especially were letters to and from the Continent feared. James I. complained of having "to meet with the dangerous and secret intelligences of ill-affected persons, both at home and abroad, by the over-great liberty taken, both in writing and riding in post, specially in and through our county of Kent." Anybody suspected of carrying a letter was searched, and, upon proof, committed to gaol. The stringency of the regulations led to their overthrow.

The battle for freedom was fought by the traders of London, among whom were many prosperous merchants, refugees from France and the Netherlands, whose trade lay entirely with the Continent. There was no trade, other than local, save with the Continent. London sent her surplus wares to the Continent, and brought back foreign produce in exchange. It was thus that our commerce began; and James was eventually forced to meet the merchants by giving them, in addition to a Master of the Posts for home, a superintendent of foreign posts. So arose a long and angry battle between private interests and the public weal. It was sought to farm the postal system for personal gain. The question divided the Council; it set the Law Courts in motion, it brought Lords and Commons into as angry collision as they have ever been.

It is a long and enthralling story, of which the upshot was a gradual betterment of posts, so that Thomas Witherings, assuming control at a time when it took two months to get a reply from Scotland, when half the postmasters were in prison for debt through having received no wages for seven years, planned a six-days' post to Edinburgh, and allotted the like time for the journey to Plymouth. And the honest fellow in his enthusiasm declared: "Any fight at sea, any distress of his Majesty's ships (which God forbid!), any wrong offered by any other nation to any of the coasts of England . . . the news will come sooner than thought." He it was who first organised an extended postal system by which private letters could be sent at private cost. Very slowly and with many checks the posts developed, reaching out from the main highways into the districts lying near. But in 1666 it took five days for a letter telling of the outbreak of the Great Fire of London to reach the Duke of Buckingham, though he was only at Worthing, sixty miles from town. Still, though for long there was no delivery of letters in London, though there was only one post-office in the whole metropolis, and though towns lying but a short distance apart could not get letters one to the other except by sending them through London at a prohibitive cost, in spite of all handicaps the postal system grew, and contributed to the spread of knowledge and the creation and expansion of trade and industry.

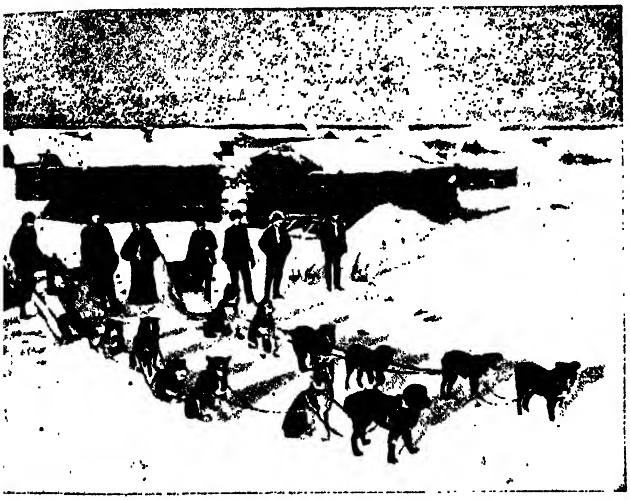
It was in 1784 that the first mail-coach appeared upon the road, the Post Office being vehemently opposed to the innovation. The coaches prepared the public for

THE COUNTRY POSTMAN DELIVERING LETTERS AND WEIGHING A PARCEL HANDED TO HIM

ZULU POST-CARRIER

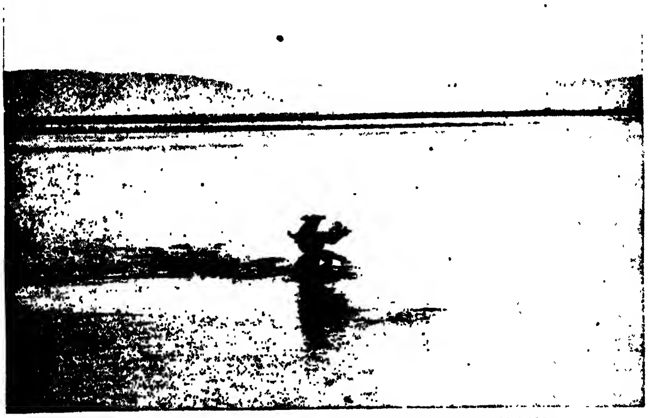
SKI-RUNNING POSTMAN IN NEW SOUTH WALES



DOG-MAIL TEAM IN KLONDYKE DISTRICT

A SIAMESE POSTMAN

SOUTH AFRICAN CARRIER



INDIAN MAIL-RUNNER CROSSING THE INDUS

the railway and the penny post. They were a great success, and even with the high prices charged for delivery were overladen with mails; the penny post would have buried them. The first train to carry mails ran between Liverpool and Manchester on November 11, 1830; and although there were not enough railways in existence at the time to afford material relief to the over-burdened horsed coaches, the dawn of a new era had come.

A PILLAR-BOX ATTACHED TO A MOTOR-BUS IN THE ISLE OF WIGHT

The penny post laid the foundation of the Post Office as a great national institution. Previously it was not national; it was the vehicle of the wealthy. The poor could not afford its help; they smuggled their letters from place to place, and so did many business houses. It was shown that five-sixths of the letters between Manchester and London were illicitly conveyed, and that one great mercantile house sent sixty-seven letter unlawfully in this manner for every one that paid the Government's due. Postal rates were incredibly heavy. Thus a single letter cost—to Brighton, 8d.; to the Lake District, 1s.; to Aberdeen, 1s. 2d.; to Belfast, 1s. 4d. Under the old scale it would have cost more than an English peasant earned in a week to send a letter of a single sheet to New Zealand, which he now reaches for a penny. Most of the fundamental reforms in relation to the Post Office have come from without. So it was with the penny post. The scheme, as we all know, was Sir Rowland Hill's. The then Postmaster-General, Lord Lichfield, declared that of all the wild and extravagant schemes he had ever known, this was the wildest and most extravagant. "The mails," he said, "would have to carry twelve times as much weight, and therefore the charge for transmission, instead of £100,000 as now, would be twelve times that amount. The walls of the Post Office would burst, the whole area in which the building stands would not be large enough to receive the clerks and the letters."

Well, in that year the letters dealt with by the Post Office numbered 82½ million. Penny post came into operation on January 1, 1840, and in the ensuing twelve months the mail went up to just short of 170 million. At present the letters number upwards of 3000 million yearly, in addition to 871 million postcards. The numbers grow year by year, while the bulk is infinitely greater. The letter which travelled to Brighton for eightpence consisted of only a single sheet, be it remembered; a letter of two sheets was counted a double missive, and was charged double fee; for a letter weighing an ounce the fee was quadrupled, and each additional quarter of an ounce added to the total cost. Thus the four-ounce letter which now goes to Brighton by express train for a penny would have entailed an outlay of several shillings in postage—more than it would cost to transmit its entire contents over the telephone.

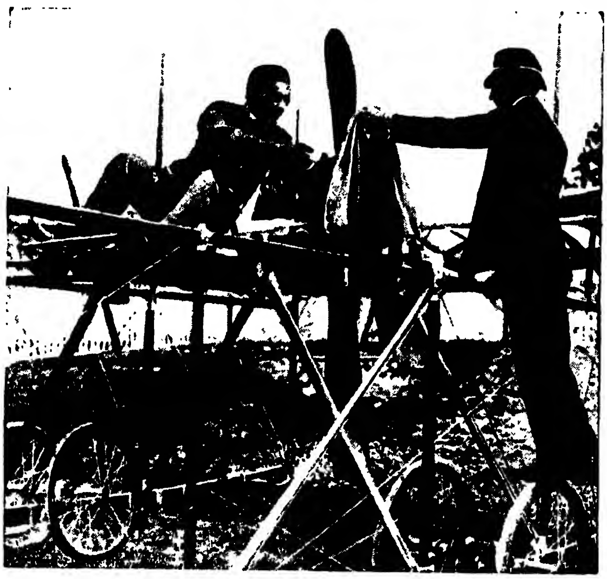
The Post Office no longer fears increase of business; it rather welcomes that desirable end. Its ambition is, if necessary, to be able to have a postman at the door of every cottage in Great Britain every day in the week, though it is true that ideal has not yet been attained. The "no-Sunday" delivery clause is operative in most parts of Scotland, in London, and in many places in the provinces. Then the islands lying in stormy seas make daily deliveries of mails impossible. St. Kilda, indeed, is at times as isolated as Nova Zembla, but her population is short of fourscore. Wireless telegraphy, when it becomes cheaper, will relieve the solitude of spots such as St. Kilda and

FLOATED TILL CALLED FOR

In the cases of lonely islands at which mail vessels do not stop, letters are sometimes enclosed in a cask with a floating flag attached to it, and are then flung into the sea. The flag attracts the attention of the people of the islands, who put off in a boat and pick up the cask of letters. This picture represents such a scene off Fernando Noronha, a convict island, 125 miles from the coast of Brazil.

Lundy Island. Meanwhile it is instructive to see what the Post Office accomplishes for more accessible islands. The mail goes daily to the Isle of Man; to the Scilly Isles twice a week in winter and thrice a week in summer, with extra steamers as occasion requires. The Orkneys have their letters, parcels, and papers six days a week; the Shetlands enjoy four or five mails a week. Alderney is served three days a week from Guernsey; once a week by an English mail which touches first at Cherbourg; and every Sunday from Poole. Even Sark, though but two square miles in area, is served every weekday in the summer, though the mails have six miles of open sea to cross from Guernsey.

The disposal of forces for mainland services is just as adroit, and many serious difficulties are overcome for the benefit of small and insignificant communities, far from a railway station. A typical example occurs in East Cottingwith, a small village in the East Riding, twelve miles from the main line. The conditions sound unpromising, yet the villagers get their letters at 7.45 every morning. How is this contrived? A mailcart leaves York in the early hours of the morning, and is met at various points by other carts, each of which covers a district not served by rail. One of these vehicles carries the Cottingwith mail back to West Cottingwith, where the letters are sorted, and the postman, after a two miles journey, which includes the passage by ferry of a considerable body of water, reaches East Cottingwith to deliver his charge in time for the breakfast-table. It takes an express train, two mail-vans, a sorter, a postman, and a ferryman to get a letter from the General Post Office to East Cottingwith, but their work triumphantly culminates at 7.45 every weekday morning.


THE FIRST EXPERIMENT IN THE AERIAL POST

And that is typical of the far-sighted and comprehensive organisation of the postal system of this country. For there are hundreds of cases such as this, of isolated villages and remote hamlets, of scattered houses and farms and even less pretentious dwellings, as solitary and far away for ordinary purposes as if in an Indian jungle. The country postman is in his way as wonderful a fellow as the man whose beat lies in London's amazing labyrinths. The one follows by-paths and little-known tracks which even an Ordnance map may ignore; the other ferrets out the citizen nomad who settles for but a day in a crowded East End rookery, or in the whirl of London City's business millions.

It is the boast of the Post Office authorities that of all the 5300 million packages that they handle in a year, every one, if properly addressed, can be traced. But not all are properly addressed. Between 20,000,000 and 30,000,000 letters or other articles fail to reach their destinations every year, owing to their bearing no address at all, or an undecipherable superscription. Some of these missives of the careless contain large sums of money. Last year a bill of credit for £1000 was found loose in a pillar-box; and the total sum contained by these "blind" letters sometimes amounts in the course of a year to nearly three-quarters of a million sterling.

But a letter must be very badly addressed for the Post Office to fail to deliver it. In the service of the department are some of the most alert of handwriting experts, who solve every day throughout the year puzzles which would baffle Scotland Yard. They deal not only with illegible writing, but with incorrect and insufficient addresses. Eight thousand letters a day pass through this department at the General Post Office, and from 30 to 40 per cent. are put right at a

SCENES FROM THE TRAVELS OF A LETTER

A LETTER-BOX ON A MAIL-TRAIN

PARCELS AT A LONDON TERMINUS

SORTING LETTERS IN THE TRAVELLING POST-OFFICE ON A NIGHT MAIL-TRAIN

TRANSFERRING MAILS TO A LINER'S TENDER

LETTER-SORTING ON A TRANSATLANTIC LINER

glance, while over 90 per cent are eventually delivered.

The officials of the "blind letter" office have won their spurs in solving deliberately planned trick addresses, as when they quickly forwarded to Lady Day a letter inscribed merely "25th March, London." But having done all that is necessary to prove their skill in matters of this kind, they no longer deal with obvious "puzzle" addresses. All such letters are now returned to their senders. Not all the troublesome letters go immediately to the "blind" office. If a postman fails to find an addressee at the first attempt, the letter is sent forth a second time, and, that failing, then the directory is consulted, and a further effort made to find the person wanted. Thus, a letter, after having been carried half way round the world for a penny, and been twice borne by hand through London, is handled by a dozen experts before it is finally declared impossible of delivery.

The General Post Office, London, is, of course, the sun around which the whole postal system revolves. It is the headquarters to which all the 230,000 employees look. There are many perfectly organised offices in the country, but none so large as this. Leaving out of account the old St. Martin's-le-Grand, and the other huge buildings devoted to telephones, to money orders, etc., etc.—each a self-contained citadel—we have in the new head office the largest building of the kind in the world, with 10¾ acres of floor space, with miles of benches and counters, with countless pigeon-holes, and elaborate, never-resting machinery for the carriage of the mails to various parts of the building. Thousands of bags of letters reach this office every day. It takes 900 postmen to deal with the correspondence of the City of London alone. In the course of the year nearly 46,000 tons of letters are dealt with by the Post Office; but if one were to make inquiry at this very moment concerning a bag of letters which reached London from a distant place two years ago to-day, the record could be found.

RE-PACKING BADLY PACKED PARCELS AT THE G.P.O.

A glance at a day in the London office gives a good general impression of the system practised. Letters arrive by rail by motor, by van, by hand; they pour in torrents into the letter-boxes, where they are received into baskets, and whisked away on endless revolving bands to the sorters. They are divided according to countries, areas, towns, districts, streets the postmen take the letters for London delivery and reduce them to further subdivisions, each man planning his own walk or beat. Then out the men go—700 of them for the first City delivery, with perhaps 200 extra men to help in carrying the loads. The first delivery begins at 7.20 and eleven other deliveries follow in the course of the day, the last being at about 7.30 in the evening. The postmen, on their return, bring in the letters from the pillar-boxes and private boxes. The collections are regulated by the supply and return of keys and tablets There are 470 sets of keys each averaging sixteen keys to the set. As a man takes his keys he records the fact in a register; as he returns them, the officer in charge of the key-room signs for their receipt, as does the superintendent of the department. At each pillar-box the postman removes one tablet declaring the time of clearance, and substitutes a fresh one. The old tablets are returned to the office at the end of each journey. In this way 10,000 of these tablets are brought into use during the course of the twenty-four hours. We no longer arm our postmen, but each of the men making the night collection carries a police whistle.

Meanwhile, provincial and foreign mails are being made up and dispatched by various conveyances to all parts of the country. Some day the mails will reach the railway termini by means of special electric underground railways, but that is

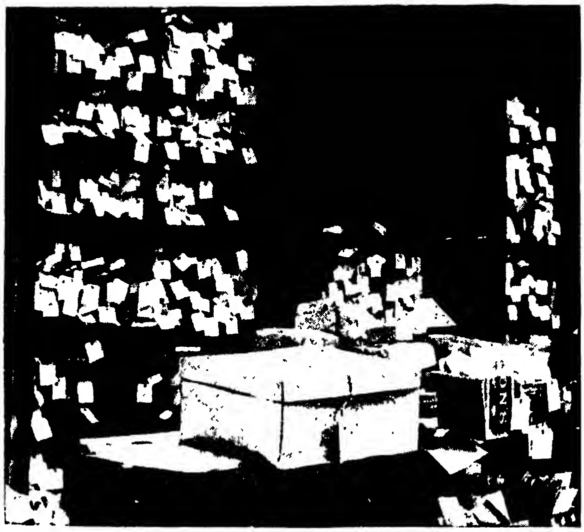
INSIDE THE POST OFFICE WHILE THE PARCEL POST IS BEING ARRANGED FOR OVERSEA DELIVERY

A TYPICAL VIEW OF THE LETTER-SORTING OFFICE IN THE GENERAL POST OFFICE

part of the future in which the reform of London traffic lies. For the moment it is interesting to glance at the overseas mail, and to note a singular colour-scheme which governs this part of the work. The mail-sacks are variously coloured for different countries. Thus, upon a grey ground appear two broad bands of red. That signifies Melbourne. Two blue stripes stand for Sydney, and a blue and a red indicate Queensland. It is a cryptogram to most of us, but on the other side of the world, or in ports nearer home where illiterate foreigners or coolies cannot read, these colourings are a rough and ready alphabet, the signs by which the mail-sacks are recognised and selected, each at its proper port. A shattered rainbow must be necessary for India, whose mail is broken up into no fewer than fifteen divisions.

But among the stacks of letters and parcels, registered and unregistered, which are going forth by this mail is one batch which will not start to-day, nor to-morrow. It is labelled Tristan da Cunha, that tiny home of four-score souls far in mid-Atlantic. It is a pathetic little mail, and has lain there, slowly increasing, for twenty-two months, no ship sailing from England having called in the meantime. The Navy's mail is more fortunate. The Post Office is in constant telegraphic communication with the fleet; and it matters not where a British warship lies, the G.P.O. follows her with tidings of home. And so the mail goes out to the uttermost ends of the earth, taking POPULAR SCIENCE to Canada for a penny, though it costs twopence-halfpenny to send it from its office to the other end of the Thames Embankment!

While the mail departments are disposing of their millions of postal packets, wonders and miracles are being wrought in the telephone and telegraph departments. Our telegraph system is the best in the world; our telephone system is not. The reason for the distinction is not far to seek. The State has had sole control of the telegraphs since 1870, and every new invention of value that has appeared has been applied to the service. The telephones have been subject to a dual authority. The Government for long would have nothing to do with the electric telegraph; they preferred the old hand-worked semaphore. But at last they were compelled to admit the value of electricity; and then, for the first time in history, communication between human beings became independent of locomotion. But the nation had to pay £10,000,000 to buy out the telegraph companies which had become established. The price was too heavy; and this fact, coupled with the low rates charged for the service rendered, occasions an annual loss to the Exchequer. Fortunately, the Post Office, as a whole, yields over £5,000,000 a year profit, and so we are spared the outcry which would otherwise arise over this commercially unsuccessful venture.



A PART OF THE DEAD LETTER OFFICE

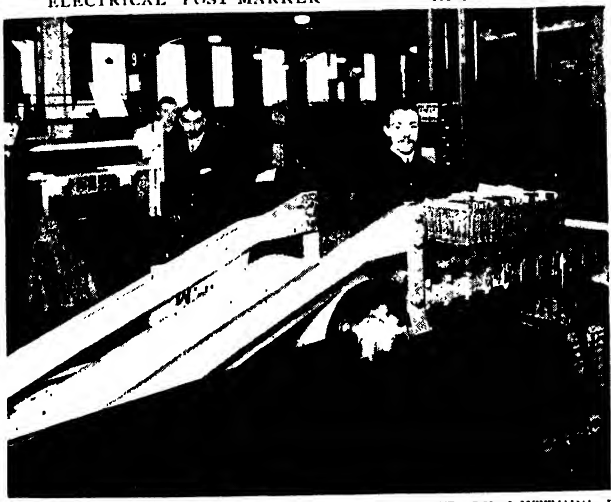
The Post Office owns about 481,000 miles of aerial telegraph and telephone wires, 78,000 miles of underground wires, and 11,000 miles of submarine cables. These figures do not include the lines newly taken over from the National Telephone Company, which brought in an additional 16,000 miles of posts and wires, with 1500 telephone exchanges, and half a million telephones.

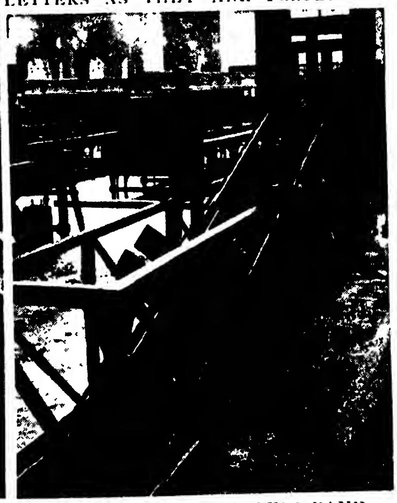
The telegraph department is a kingdom of wizardry. Here we have the apparatus which gives the United Kingdom its Greenwich time, correcting clocks by electric current, operating time-balls, and firing the time-guns in arsenal and dockyard. At 8.58 every morning all work ceases in the department; two minutes later there comes from Greenwich the signal, N.I.N.E., which, passing through a governing instrument at headquarters, runs

TIME-SAVING MECHANISMS IN THE G.P.O.

ELECTRICAL POST-MARKER

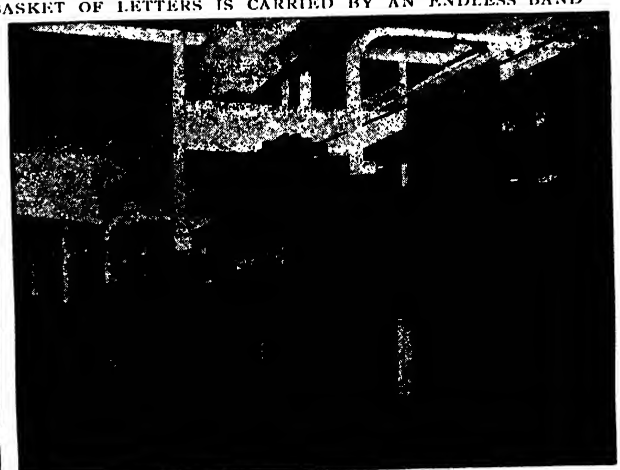
RECEIVING THE LETTERS AS THEY ARE POSTED





TWO PICTURES SHOWING HOW A BASKET OF LETTERS IS CARRIED BY AN ENDLESS BAND

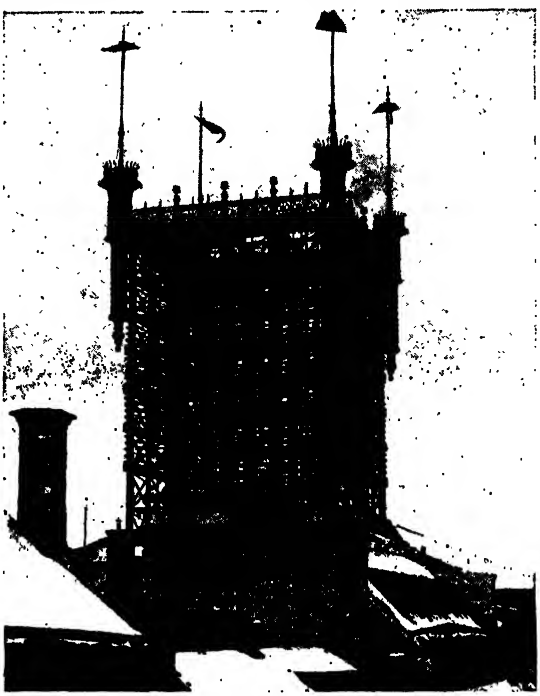
A SORTED BAG TRAVELLING TO THE MAIL-CARTS



A BASKET ON A RAILWAY CARRIER PASSING FROM DEPARTMENT TO DEPARTMENT

with the speed of lightning throughout the entire telegraphic system of the kingdom. And so Great Britain knows what o'clock it is according to Greenwich.

Here, too, is the apparatus by which the wires of the country are tested every morning. Meteorological conditions are constantly causing trouble. The wire to York is always bad in the early morning, owing to the fact that the fogs of Fenland offer great resistance to the current until the sun gains power enough to dry the air. But a snowstorm or hurricane may cause disaster, and the position of the fault has to be located from London, whether it be at Edinburgh, at Newcastle, or nearer the capital. And it is found, by a process of elimination. Tests show to which point the line is working correctly, and after that it is easy to discover where the trouble begins. They preserve in the Post Office museum a relic of recurrent faults extending over years. It is a section of a large branch of a tree, scored in many places by the effect of contact with the telegraph wire. Only at certain times and with the wind in a particular direction did the fault arise. At such times there would be intermittent short-circuits, caused by the wet branch striking the wire. At each rebound the fault disappeared, and linemen examining the route would see the tree standing innocently remote from the wire, and pass it by. But the branch made one assault too many upon the wires; it was caught at the moment of actual contact, and was at once sawn off, to reveal the record of thousands upon thousands of such collisions, in the form of a score of deep grooves, hidden upon its under side. The science and skill of men had been baffled for years by that one swaying arm of timber.



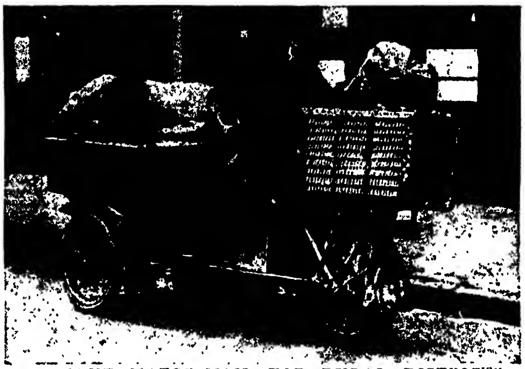
WHERE THE TELEPHONE SERVES THE WHOLE COMMUNITY—THE EXCHANGE AT STOCKHOLM, SWEDEN

It would take many chapters to describe adequately the wonders of the apparatus used for the sending of telegrams—instruments which enable four, six, and even eight operators simultaneously to send messages over one wire—four at each end; instruments that deliver their messages on typewritten slips; that employ photography, and, with messages proceeding simultaneously from both ends of the wire, automatically photograph, tone, fix, and in ten minutes deliver the message in strips ready for gumming. Among the 1100 sets of apparatus in use are instruments which typewrite their messages ready for the hand of the addressee, and some that actually reproduce in enlarged facsimile at one end of the wire the characters, letters, or drawings executed by the sender at the other end of the wire.

One instrument, the Baudot, gives six or eight operators the independent and practically simultaneous use of one and the same wire, so that eight messages travel at the same time over one line instead of over eight lines. Rome and Buda-Pest are the farthest points reached by direct working, but by taking advantage of other cables the Post Office can, of course, telegraph round the world. Moreover, it is encircling the land with its wireless telegraphy stations, and already has a service of over 40,000 radio-telegrams a year. The most significant wireless development, however, is Imperial. A considerable step towards wireless connection throughout the Empire is now being taken by the erection of Government wireless stations extending from London to Egypt, Aden (Arabia), Bangalore (India), Pretoria, and Singapore. Canada, of course, is already equipped, and Australia,

no doubt, is only left out of the scheme because that Commonwealth contemplates establishing an installation of its own. The linking up of all stations will emphasise afresh the idea of the immensity of the Empire. From 20,000 to 25,000 messages pass over the cables to the Continent every day, many of them on the telephone cables running to France and Belgium, so that telegram and telephone message proceed side by side, so to speak, over the same line.

The telephone department is another source of wonder to the visitor, who must think in hundreds of millions if he would grasp the statistics as to calls. The point of interest is that, in addition to the multiplicity of channels for land calls, of which the farthest over British soil is that from London to Wick, 730 miles, it is now possible for some 300 towns in England, Scotland, and Wales to speak direct to Paris, and many to other French towns, and to Belgium and Switzerland. An enormous extension of facilities has been effected during the current year by the laying of a new cable which embodies a new principle—the insertion at regular intervals of inductance or loading coils, which help to counteract the ill effects upon speech-transmission produced by the electrostatic capacity of the cable wires. This departure has at a bound extended by 300 miles the range of submarine telephone cables. A further development of the present year is the perfection of what is popularly termed a phantom current, a current borrowed from two existing cables and made to act for the transmission of speech as if the cables were threefold, so adding 50 per cent. to the capacity of the cables.



A LIGHT MOTOR-MAIL FOR RURAL DISTRICTS

We may expect swift and notable advances in our telephone system, better and cheaper service, and extensions inconceivable a few years ago. Even now the telephone has greater possibilities than we all recognise. We may send letters by telephone; we may have a twenty-four hours [illegible] forecast telephoned—a boon to h[illegible]ers, to intending holiday-mak[illegible] concerned in outdoor pu[illegible] and market gardeners may have the telephone for £3 a year, provided that there are five subscribers to a line. Some day we shall have a great installation of automatic telephones, but their introduction into cities in which the old system is established is less easy than in the case of a new town, such as the American centres in which they now flourish. A first-class telephone exchange represents an outlay of £100,000, and the Post Office trembles at the thought of scrapping those which are new.

All told, there are about 600,000 telephone subscribers in Great Britain. The Post Office expects soon to have four times as many; by thoroughly popularising their methods they ought to have ten times their present number. When telephone rates are as cheap in Great Britain as they are, say, in Sweden, they will become practically indispensable adjuncts of every well-ordered household and business.

Such, then, are some of the outstanding features of this enormous State enterprise which, little by little, has been evolved from a congeries of chaotic negations. Anciently the most successful postmaster was he who best prevented the public from having access to the posts; to-day, the best is the Postmaster-General, who multiplies opportunities of bringing the public in touch with the many departments for which he is responsible. We need a universal penny post; we need a cheap and sensible rate for magazines; we need cheaper telephones, and still cheaper telegraphs.

Penny postage was to bring ruin upon the country; and we are now told that a universal penny post would occasion a loss of about £400,000 a year, which is £150,000 less than the increased profit of 1911 over the preceding year. The only reason for the delay of cheaper telephone rates to the Continent was that it was feared there would be such an increase of telephoning as to render the existing cables insufficient. The Post Office is the biggest enterp[illegible]t the greatest Empire of the world h[illegible], but in many respects it is still in its [illegible]ancy. All that it needs is a small portion of the courage of a Sir Rowland Hill.

GROWING CLOTHING FOR THE MEN WHO RULE THE WORLD FROM THE TEMPERATE ZONE

SUPPLIES FOR THE WORLD'S WOOL MARKET

WOOL AND WOOLLENS

The Ancient Staple. England's Oldest Export and Industry, to which Kings Looked for Revenue

MATERIALS THAT FAIL TO KEEP THE PACE

THE commerce of the United Kingdom has ever been largely concerned with wool or with articles made from wool. In ancient days, before the use of coal changed the character and the currents of our trade, the United Kingdom was a great producer of wool and a great exporter of the raw material. The use of coal has changed all that. The sheep of the United Kingdom have decreased in number, we have little or no wool to export, and we import an enormous quantity for manufacturing purposes. The change is typical of that revolution in the British economic position which swept our people into the towns, and changed an agricultural into a manufacturing nation.

Our earliest records of Customs duties are concerned with wool. King John levied an export duty on wool, and in a statute passed in 1266, in the reign of Henry III., a reference is made to the payment into the Exchequer of the Customs duty on wool received by the collector. In 1297 there was granted to Edward I., "in aid of his war with France," a Customs duty of forty shillings for every sack of wool exported, for the space of two or three years, "if the said war lasted so long;" and this was in addition to an existing Customs duty of half a mark (6s. 8d.) for every sack of wool and woolskins. Be it observed that these were export duties, for it was quite unnecessary to import. There seems little doubt that the British exports of wool were so valuable, and indeed indispensable, that the Flemings and others who bought them to carry on their industries had to pay the duty, just as to-day we should have to pay an export duty on cotton if the United States were to levy one, because there is no sufficient alternative source of supply of that material, as we saw in the last chapter.

It is probable that a Customs duty on wool existed long before the earliest date named above, for in the charter known as *Carta Mercatoria*, granted by Edward I. in 1303 to certain foreign merchants, reference is made, in setting up a new wool export duty, to an "ancient" duty of the same character. The liberty of trading in England was granted to merchants of "Germany, France, Spain, Portugal, Navarr, Lombardy, Tuscany, Provence, Cathalonia, Our Dukedoms of Acquitain, Tholous, Turein, Flanders, Brabant, and all other lands and forrein places by what names so-ever called," but in return they were required to pay "New Custom," "Alien," or "Petty Custom" duties, amongst which was:

"*Item:* For every *sack of wooll*, which the said merchants, or others in their names do buy, and out of this kingdom transport, or buy to transport, shall pay *fourty pence* over and above the antient Custom of half a mark, which formerly was paid."

This reference to the existing duty leaves no doubt that revenue was gained from the export of wool during a period long before the year 1303.

At a later date we find the British Parliament prohibiting the export of English wool in order to encourage home trade. Thus, in 1463, in the reign of Henry VI., we find it enacted that no wool shall be exported save to Calais, then part of the British dominions:

"Because the chief and principal commodity of this realm of England consisteth in the wool growing within the said realm, and to the intent that sufficient plenty of the said wools may continue, abide, and remain within the said realm, as may competently and reasonably serve for the occupation of cloth workers."

And "towns of the same realm [illegible] into great and piteous desolation, ruin and decay, by the occasion of idleness may be, if God

will, multiplied in inhabitation, and by labour restored to their ancient joy and prosperity."

It was in connection with wool, sheepskins, and leather, and, in a lesser degree, tin and lead, that the word "staple" came into use. These things were "staples of the kingdom," and liberty to trade in them was granted to companies of merchants who were allowed to form markets in them at certain appointed towns. The appointed town was a "staple" town, and the articles themselves "staple" commodities.

The most extraordinary tricks were played in our early commercial history with these staples. They were the natural prey of kings hungry for revenue. The staples were moved from place to place so bewilderingly that it appears marvellous that commerce survived at all. Thus, in 1328 the staples were abolished, and merchants allowed to go about their business freely. In 1348 Calais was appointed the staple; in 1352 it was set up in London; in 1353 an "Ordinance of the Staples" moved them from Calais to certain English, Welsh, and Irish towns; in 1363 Calais was again favoured; in 1369 the staple was again removed to England; in 1376 Calais had her staple restored to her; in 1378 business in staples is permitted at Southampton, and so on through a remarkable series of capricious transmutations.

In modern times the word "staple" has survived with a modified meaning, and we now use the word to denote a main or chief industry. And wool and things woollen are still a staple, if, happily, not in the ancient sense.

What the industrial revolution did for the British wool trade will be gathered from the important record below, which shows the progress in British consumption of wool since 1775.

The statement shows the various proportions of imported and home-grown wool which have been used in the period. We see that in 1775, and even as late as the first twenty years of the nineteenth century, the British wool industries were almost entirely fed by British sheep-raisers. Even as late as the middle of the nineteenth century, we used more home-grown than imported wool. In 1870–74 the imported wool had taken the lead, and in the last forty years the home supply has tended to fall, while an ever-increasing amount of foreign and Colonial wool has been brought in. In a century our imports for home consumption of imported wool have risen from a negligible quantity to five hundred million pounds a year.

In columns D and E of the table are shown the additions of material from (1) wool imported on skins, and (2) shoddy, mungo, etc. The latter item is of much importance. It will be seen to what a considerable figure it has risen.

The use of these second-hand wool materials has grown of late years, first from the demand for cheaper cloths, and second from the shortage of wool relatively to demand. "Shoddy" or "pulled wool" is made by tearing up soft woollen discarded garments such as underclothing, stockings, etc. "Mungo" is made from used cloth, tailors' clippings, etc. Various other fancy expressions, some of a sweeter sound, are used to describe different varieties of shoddy and mungo. The public has got hold of the word "shoddy," and its ignoble sound

TABLE OF THE BRITISH CONSUMPTION OF WOOL FOR A HUNDRED YEARS

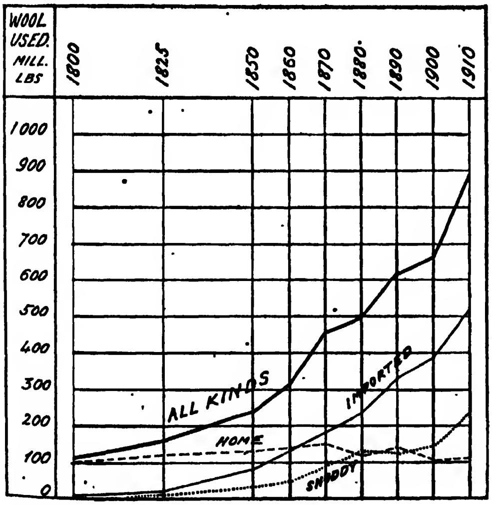
Year	A Imported Wool	B Home-Grown Wool	C Total of A and B	D Wool from Imported Sheepskins	E Shoddy, Mungo, etc.	F Total of A, B, C, D, and E, *i.e.*, Total Consumption	G Population of United Kingdom	H Consumption Per Head of Population
	Million lb.	Million lb.	Million lb.	Million lb.	Million lb.	Million lb.	Millions	lb.
1775	2·0	80·0	82·0	—	—	82·0	13·0	6·3
Average of Years								
1800–19	10·0	100·0	110·0	—	—	110·0	18·5	5·9
1825–29	28·9	114·4	143·3	—	10·0	153·3	23·2	6·6
1850–54	82·0	123·0	205·0	6·0	30·0	241·0	27·8	8·7
1860–64	122·6	134·5	257·1	9·0	45·0	311·1	29·2	10·6
1870–74	191·2	150·4	341·7	23·0	89·0	453·7	31·9	14·2
1880–84	234·8	118·9	353·6	20·0	123·0	496·6	35·2	14·1
1890–94	342·8	129·8	472·6	32·2	118·0	622·8	38·1	16·3
1900–04	379·7	104·8	484·5	29·6	145·0	659·1	41·9	15·7
1910	506·4	105·9	612·3	37·0	226·0	875·3	45·4	19·3

fairly well consorts with its real meaning, although quite decent cloths are made out of yarns in which a certain proportion of shoddy is combined with new wool. The reader will gather from the extraordinary figures of the 1910 line of the table what a large proportion of second-hand wool entered into the production of modern wool fabrics. We see that the total consumption of all kinds being 875 million lb., shoddy accounted for 226 million lb., or about 25 per cent. of the total material used in 1910.

The statement may be relied upon, as it is based upon the record of the Bradford Chamber of Commerce. The import figures are from the Custom House; the estimates of shoddy, etc., are those of the officials of the Chamber.

When we speak of the increased price of wool, we refer to the change in the last ten years. The price of wool fell continuously until 1901–2, when the price of imported wool fell to 7½d. per lb. Since then, it has risen to about 10d.

Shoddy does not appear to be entirely a modern invention; it is on record in a British statute of the reign of Edward IV. that there were complaints as to "rubbish" being mixed with wool.



BRITISH CONSUMPTION OF WOOL AND SHODDY

This diagram shows how our consumption of wool has increased in 110 years. The home-grown supply has fallen, but the imports have increased enormously. The dotted line shows the consumption of shoddy, which has greatly increased since 1900.

Commerce in the material is an anxious matter for the manufacturer; and it is unfortunate that in regard to wool, as in regard to so many other materials, the beginning of the twentieth century has witnessed a more rapid expansion of demand than of supply. European manufacturers cannot base a sufficient industry upon the fleeces of Europe, and it is fortunate that Australasia and South America have proved ready to lend themselves to sheep-raising. Progress in wool production in these parts of the world, however, has had many checks.

The position which exists is a curious one. During the past generation the sheep of Europe have been threatened with extinction. Germany lost about one-half her sheep in the last twenty-five years of the nineteenth century. There have also been falls in Russia and in France, although the decline in the United Kingdom has not been very great. The fall in England would have been greater but for the considerable conversion of arable into pasture since the 'seventies. So we see Europe, with woollen and worsted industries ever calling for more wool, increasingly dependent upon outside sources for the all-important material.

Unfortunately, the world at large has not responded to the demand. At the end of the nineteenth century, about one-half of the Australian flocks were killed by drought. Australia is subject to climatic catastrophes which check her pastoral industries at not infrequent intervals. In 1891 Australia had 105,000,000 sheep; in 1903 she had but about 50,000,000. There has since been recovery, but at any time droughts may recur and sweep away the increase. Australia has also to reckon with the devastations of the rabbit, which has played havoc with her pastures, and therefore with wool production.

New Zealand does not, like Australia, suffer from the check of recurrent droughts, but her wool supplies have been checked by the world's call for meat, which limits the growth of the flocks. A large number of the New Zealand exporters ship lamb, and the consequence is that there is no rapid growth of New Zealand wool output.

South America is one of the most important wool suppliers, but here, again, many causes have operated to check the growth of sheep. Corn and cattle have increased at the expense of the flocks of late years, and there seems to have been actual decline of sheep in Argentina. South African progress was checked by the war; there has since been recovery, but the Union has not yet as many sheep as the United Kingdom.

The United States, in spite of her enormous area, has not more than about twice as many sheep as the United Kingdom,

and the number tends to decrease rather than to increase, making the American manufacturer more and more dependent upon imports. There has been a rapid contraction of the American pastoral area with the extraordinary growth of the American population through natural increase and immigration combined, and cattle are always competing with sheep in the decreasing pastoral areas.

Altogether, then, the wool position is a difficult and somewhat serious one, and it is quite probable that we may see much higher prices for wool. Undoubtedly the world possesses the means of increasing wool indefinitely, but it is not apparent how any considerable change in the position can obtain in the near future, and it is more probable than not that the industry will have to contend with a progressive shortage for some time to come. It is a matter in which the world's woollen and worsted manufacturers would be well advised to take a leaf out of the book of the world's cotton masters, and organise international conferences with a view to stimulating the production of material.

Substitutes will undoubtedly be encouraged; and it may be remarked, in regard to the table on page 1834, that a very considerable amount of cotton is now employed in the woollen industries, in addition to the increasing employment of second-hand wool. It is pretty clear that the great majority of people rarely obtain an all-wool garment.

The bringing of wool to market is a curious process which is undergoing significant symptoms of change. The chief wool market of the world is London; and it is strange to observe how the material, which is chiefly used in Yorkshire, hundreds of miles from London, is landed on the Thames, dealt with commercially in London, and afterwards sent on to its place of use.

Of the Colonial wool brought to the United Kingdom in 1911—viz., about 500,000,000 lb.—by far the greater part came to the Port of London. Some of it is re-exported in the merchant trade, a fact which itself points to imperfection of organisation, for it is strange that wool should be brought to London, landed, warehoused, brought to auction, sold again on foreign account, and again shipped abroad, instead of being taken directly from its place of origin to its place of use. In 1911 £13,000,000 worth of imported wool was re-exported from the United Kingdom, chiefly to the Continent of Europe. This is obviously a thing which cannot last for ever, and as years go on an increasing proportion of wool will be handled in a more scientific manner, to the loss of London middlemen. At one time, lack of shipping facilities had much to do with such indirect and wasteful traffic, but now German and French vessels ply between Australasia and Argentina and Continental ports. The foreign buying of wool in London is falling, but is still enormous, as will be gathered by the figures we have given.

The re-exportation of wool from London to the Continent of Europe is only a trifle more extraordinary, from an economic point of view, than its sale by auction in London, and prolonged handling in London, for use in Yorkshire. A certain proportion of wool more sensibly finds its way to Hull or Goole, and Argentine wool for the most part finds its way to Liverpool.

A great deal of commercial waste occurs during the handling of wool in London. The wool warehouses do not adjoin the railway lines. There is a deal of unnecessary carting, and obviously this has to be done twice. It is the custom to handle wool in small lots, and there are six series of auction sales during the year, although it has been suggested that two of the winter ones should be dropped.

We need not be surprised to learn that the direct sale of wool in Australia is a growing feature of the trade, and that the Argentine wool is almost entirely sold direct, the material being bought in South American markets. It is inevitable that the machinery of commerce must become as efficient as the machinery of industry; and when one thinks of the scientific accuracy of the looms and other machines employed in the woollen trade, and contrasts it with the clumsy bringing to London of wool to be used at Bradford, one hundred and ninety miles away, we are again reminded that Commerce has much to do before she is a perfect handmaiden of Industry. To find a fitting parallel for the course taken by most of the wool that comes to the United Kingdom, we should have to imagine a London newspaper proprietor so foolish as to have his newspaper

set up by compositors south of the Thames, the type carted north to Holloway or Islington to be printed, and the papers carted again from Holloway or Islington to Fleet Street to be published.

It is difficult to estimate how much the waste of the present system amounts to. Our imports of wool in 1911 were worth £36,000,000, and it is probable, therefore, that 5 per cent., or say £1,800,000, is a low estimate of the cost of the uneconomic handling of the product. In the long run the sum wasted must be loaded on to prices to the consumer, and every such load checks the development of industry.

Turning from the material to the manufacturing industry, wool is, of course, the oldest of our textiles, and we seat the Lord Chancellor of England on a "woolsack." We owe it to the Flemings, who settled near Norwich at the end of the thirteenth century, and in the course of time made that town the most important manufacturing centre in the country, and the second largest town in England after London. The history of British commerce is full of legislative attempts to foster the woollen industry. Perhaps the most remarkable was the enactment of 1666, which directed that all bodies must be buried in woollen shrouds in order to encourage the manufacture of woollen cloth. It is not surprising to learn that a large number of deceased Britons evaded this law, and twelve years later it was re-enacted in a more stringent fashion, with due provision for its enforcement. The incumbent of every parish was directed to investigate every burial, and to certify that the deceased was duly provided with his legislative piece of woollen, and official searchers were established to assist the incumbent in his unpleasant duty. They were great jesters, the legislators of these "good old times."

In spite of such expedients, the old English woollen industry did not always flourish. The competition of Ireland came to be felt severely, and in 1693 the Irish Parliament was induced or compelled to levy an export duty on Irish woollen exports in order to assist the English manufacturers, while in 1699 the Irish industry was crushed by the English Parliament prohibiting Irish exportation. A century later we find Arthur Young writing that "of all the great fabrics of England, that of wool is least prosperous, and has been most complaining."

Textile machinery began with the cotton trade, but the inventions of Hargreaves, Arkwright, and others soon spread, with appropriate modifications, to the woollen industry, at the end of the eighteenth century. Unfortunately for Norwich, her people refused to have anything to do with the new-fangled ways, with the consequence that her textile trade left her.

We are not concerned here with the intimate details of manufacturing processes, but it is necessary to point out the essential difference between the two great branches of the wool textile industry. In general terms the "woollen" trade refers to the entire industry, but technically the trade distinguishes between a "woollen" industry and a "worsted" industry. Woollen cloths are woven from yarn which is spun from short-fibred wools, which are "carded" or drawn between parallel surfaces covered with teeth, so that the short fibres are blended into a uniform mass. Worsted cloths are woven from yarn spun from long-fibred wools which are not "carded," but "combed," the long fibres being drawn out parallel with each other. However, there is not always a clear line between woollens and worsteds, since both woollen and worsted yarn may be used in the same cloth. Again, cotton yarn, silk yarn, and shoddy yarn are worked up with yarns of wool, and the possible combinations are endless, as is shown in practice by the extraordinary and frequent caprices of fashion.

With this brief reference to technical processes, we may turn to the table below, which shows the progress of British exports of woollen and worsted goods since 1860.

UNITED KINGDOM WOOLLEN AND WORSTED EXPORTS

	Flocks and Shoddy	Tops, Noils, etc.	Yarns	Cloths	Apparel	Grand Total
	£	£	£	£	£	£
1860	145,796	—	3,843,450	12,158,710	700,000	16,847,956
1870	116,162	—	5,182,926	21,664,953	700,000	27,664,051
1880	546,671	—	4,222,693	17,265,177	1,900,000	23,934,541
1890	406,517	1,390,065	5,260,925	20,418,482	1,700,000	29,175,989
1900	328,324	2,125,939	6,123,349	15,682,154	1,700,000	25,946,037
1910	349,720	5,179,701	9,046,360	25,079,197	3,000,133	42,655,611

This record shows that while exports were almost stationary in value between 1870 and 1900, there has been a considerable increase in the shipments in recent years.

The analysis shows that it is in cloths that shipments have been most stationary. The explanation of this is to be found in the growing industries of other countries, and in foreign protective tariffs. Most progress has been made in the exports of apparel, of yarns, and of "tops" and "noils." These terms refer to the product of the first processes applied to the long-fibred wool. When such wool is combed out ready for the worsted yarn-spinner, the product is called a "top," and the short wool combed out, which is used by the woollen yarn-spinner, is the "noil."

To judge whether British commerce in woollens and worsteds has made satisfactory progress, we may compare the British exports of cloths of wool with those of France, Germany, and the United States. This is done in the following statement, prepared by the Board of Trade, for the years 1880 to 1908. It is not possible to give a satisfactory comparison for a longer period.

FOUR NATIONS' EXPORTS OF WOOLLEN AND WORSTED CLOTHS COMPARED

Year	From United Kingdom	From France	From Germany	From United States
	Million £	Million £	Million £	Million £
1880 ..	17.3	14.8	10.8	0.05
1885 ..	18.8	13.2	10.2	0.05
1890 ..	20.4	14.5	12.4	0.03
1895 ..	19.7	12.9	10.9	0.07
1900 ..	15.7	9.1	11.6	0.15
1905 ..	19.6	7.7	14.4	0.09
1908 ..	19.2	7.8	12.7	0.10

It will be gathered from this record that to increase exports of woollen and worsted cloths is not an easy matter. Here we have the figures of the four leading commercial nations. The exports of the United States of America are negligible, and may be brushed aside. Turning to Germany, we see that, great as has been German progress in other directions, her exports of woollen cloths show but little increase, and that not of a steady character.

Even more remarkable is the case of France. We see that French woollen exports have diminished by one-half since 1880. The French are expert in fine woollens, and it is not a little strange that they have failed to maintain sales of their beautiful productions. On the whole, the British figures come very well out of the comparison, being about as great as those of the other three countries put together.

The imports of woollen and worsted yarns and cloths into the United Kingdom are not very great, and show in recent years a tendency to diminish. The imports since 1860 have been as follows.

WOOLLEN AND WORSTED IMPORTS OF THE UNITED KINGDOM

Year	£
1860	2,100,000
1870	4,700,000
1880	8,900,000
1890	9,900,000
1900	10,700,000
1910	8,400,000

Thus, our imports of this kind in 1910 were less in value than thirty years ago, while, as will be seen by the table on page 1837, our exports in the same period have about doubled in value. It is apparent, therefore, that the trade has held its own very well. One wonders what the gentleman who is sometimes called the Merry Monarch, in whose reign that ponderous legislative pleasantry about the compulsory burying of bodies in British wool was enacted, would have thought of a British exportation of woollens worth the revenues of many kingdoms in his day.

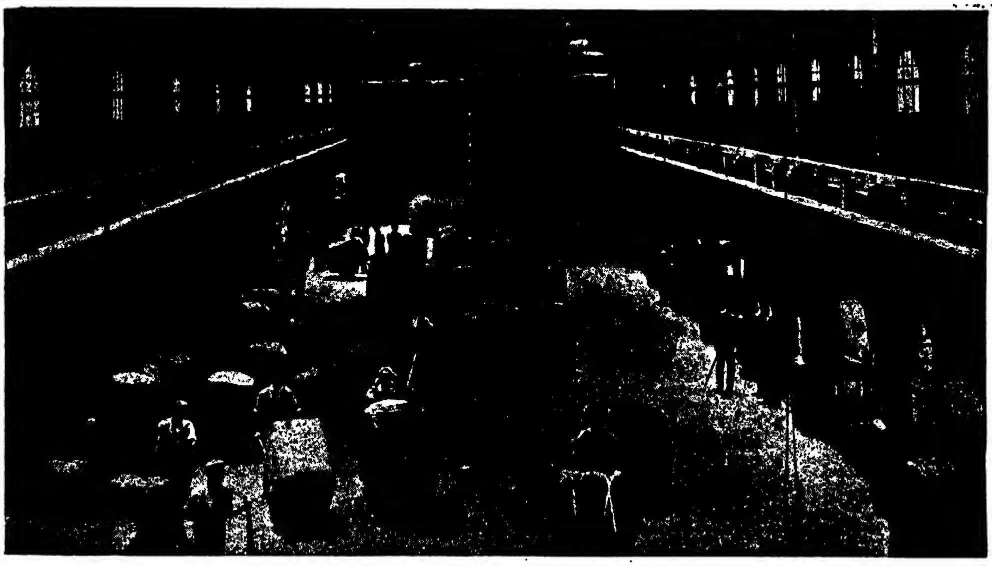
As in the case of the cotton trade, there is no reason to believe that the trade has by any means reached the limit of expansion. Consumption in the home market is larger than it was, and it is bound to grow as wages improve. If we imagine the 9,000,000 families of the United Kingdom able to spend no more than £10 per family upon manufactures of wool, we should have a home trade worth £90,000,000. The existing home trade is very much smaller than that, probably not greater than £50,000,000. The sum named as a possible consumption per family is much smaller than the conception of a high standard of comfort demands; we may look forward in confidence to a time when an average family of five persons will consume £20 or more of woollen goods in a year; and such a consumption, even if we had no export trade, would almost treble our production.

As to exports, there is a more limited field than for cotton goods, since woollens are not needed to any great extent in many lands. There is also the possible rise of great woollen and worsted industries in Australasia, in South Africa, and in South America to take into account; nevertheless, as we have said in other connections, the

rise of the standard of life and comfort in the world at large is likely to proceed so rapidly in the near future that, even in the export trade, further expansion is possible, and, with due enterprise, probable.

The woollen and worsted industries support a certain number of middlemen. The London wool-dealing may not be entirely economical, but it is free from gambling in "futures." Even the Yorkshire wool merchant is usually in part concerned in manufacturing processes. The old wool-stapler has become the "top-maker," who not merely buys wool, but either combs it himself or has it combed by a "commission woolcomber," and supplies the spinner with a partly manufactured article, the "top," ready for spinning into yarn. The spinners, again, deal for the most part directly with the manufacturers, without the intervention of a yarn agent. The manufacturers sometimes deal directly with their customers in the home market—always so with large customers, such as the great wholesale manufacturing clothiers of the North; and more rarely with the retail tailor. The merchant, able to show a range of patterns drawn from a circle of makers, has an obvious economic value. In the export market for cloths the merchant intermediary still plays a large part. Nevertheless, the time will probably pass when a manufacturer, as is now so often the case in some trades, merely carries out the instructions of an export merchant, and has not the faintest idea of the machinery of the export trade. The modern export manufacturer is beginning to realise that he is often better able to keep his markets when he studies them himself.

The caprices of fashion have a great influence upon the fortunes both of the woollen and worsted branches. The manufacturer is engaged in a continual attempt to keep pace with the freaks of human, and especially of feminine, fancy. Fashion ranges between woollens and worsteds, and is not content merely to worry the spinner and the manufacturer with sudden desires for nothing but tweed, or nothing but fine woollen cloth, or nothing but stripes, or nothing but spots, or as the case may be.



WOOL-BALES IN THE WELLINGTON HARBOUR STORE, ON THEIR WAY FROM THE NEW ZEALAND FARMER TO THE YORKSHIRE MANUFACTURER

Unfortunately, fashion can hit the manufacturer even harder. It may suddenly reduce by one-third or more the quantity of dress stuff required, which is far worse for trade than a sudden breaking out into a particular texture or particular style. The craze for attenuated skirts which swept over society in 1911 had a considerable influence upon production in the wool textile industries. As suddenly there might be a demand for full skirts and 50 per cent. more material. Between style and quantity the wool industries find themselves quite unable to make for stock. They have to be constantly on the alert, ready to adapt themselves at a few weeks' notice to the use of light or heavy yarns, and of any and every variety of materials whose name is legion.

IN THE EARLY DAYS OF AGRICULTURE

A SCENE IN THE DAYS WHEN MAN FIRST TURNED METAL TO ACCOUNT

From the painting by Mr. F. Cormon entitled "The Bronze Age."

THE OWNERSHIP OF LAND

How the Ox Created an Aristocracy of Wealth, and Brought on Slavery

THE ORIGIN OF VILLAGE COMMUNITIES

One of the most perplexing problems of social evolution is that concerning the origin of private ownership in land. The matter has some bearing on modern politics, and for this reason there are few writers who approach it without bias. Since G. L. von Maurier published his work on village communities in 1854, it has widely been assumed that in the early agricultural state all landed property was held by a community of free farmers. In this view, the lord of the manor, with his mixed following of serfs and free tenants, is the product of a later age. He is supposed to have imposed his rule by force of arms on the commune, and reduced the free men to a position of slavery or dependency.

In other words, the individual ownership of land is said to have been brought about by a system of feudalism based on war and conquest, a long time after agriculture had been carried on by farming communes. In particular, the nations of Northern Europe are presumed to have originally been largely composed of free village communities, holding the land in common, so that the modern movement towards liberty is, in a way, only a return to a more ancient state of freedom. The existence of primitive village communities has been traced from Ireland to India, by one school of writers, and they suggest that it must have obtained throughout the world in the early agricultural ages.

Now, undoubtedly, the institution of folkland is an historical fact. In many parts of Europe in the Middle Ages there were villagers who formed, so to speak, an organic and perpetual joint-stock company in regard to the soil they lived upon. The individual had no property in the land, but only the right to till a field, to pasture his cattle in a meadow, and collect wood from a certain part of the forest. In some cases even this right of usage was not permanent, and every year the village elders assembled and divided the land afresh, apportioning to each commoner his share of arable land, pasture, and forest. It was a sort of communism. But the question is whether it was a somewhat late development of village life, like the republicanism of some mediæval cities, or whether it was a primitive tribal communism.

It is clear that in the hunting stage of society there is no individual ownership of land. When a tribe lives on wild food, the marking out of small divisions will be useless, even if the thought of dividing up the territory occurs to the hunters. If a large herd of game enters any part of the tribal territory, all the tribesmen hunt it down for food; and usually the man who first wounds an animal or traps it acquires the right to it. Sometimes, when food is abundant, a tribe will not object to the presence on their hunting fields of men from neighbouring tribes. On the other hand, when game is scarce and the pressure of population is strongly felt, wars break out between tribe and tribe, and there are invasions of territory. Thus the Bantu races from East Africa dispossessed the Bushmen of the south of many of their hunting grounds; and in Northern America the Algonquian Indians, who had spread over all the forested regions of Canada, were deprived of some of their territory by stronger southern tribes. But even when inter-tribal strife of this sort is frequent, it does not in the hunting stage lead to any private ownership of land. The thing is an economic impossibility.

It is also difficult for the idea of a permanent division of the soil to be put into practice in the pastoral stage of culture. The herds must be often moved to fresh pasture grounds when the art of growing roots for them is still unknown; and neither the cattle nor their owners would survive

if each family were restricted to one spot. The united possession of a wide tract is necessary alike to herders and huntsmen. The land which the Bechuanas inhabit, for instance, is the common property of the whole tribe, and is used as pasture for their herds. Another pastoral people of South Africa, the Damaras, have no notion of permanent dwelling-places. The whole country is considered public property, and a man who takes his herd to a certain spot is regarded as the master of it, so long as he chooses to remain there. Of course, when he moves, the land is worth little or nothing for the time, as his cattle have left it bare.

The fact is that in primitive society land by itself is not of very great value. It is certainly never worth a man's while to settle on it. It is the same at the beginning of the agricultural age. Permanent private ownership of land is the last thing that a family requires. It would mean starvation. The primitive farmer is a wanderer. Using no manure, he exhausts the soil very quickly; and the next season he moves on, and breaks up another patch of virgin ground. Moreover, this part of the work is generally performed by his womenfolk, and he, seeking for fresh pasturage for his cattle, is as anxious as the women are to remove to a new place. So we see that man has been more or less of a migrant for hundreds of thousands of years. Therefore, the idea of the private ownership of soil did not occur to him.

Man Made Animals His Allies Before Subduing the Land

All that the early farmer requires is a temporary right to the land he is cultivating and exhausting. Generally speaking, it is not until the hoe is displaced by the plough drawn by beasts that agriculture in a large way becomes widely practical. The hoe is too feeble an instrument for the conquest of the soil; and though in parts of ancient America, where guano was available, it may have been used with surprising results, the civilisation of the modern world—the civilisation which has lasted and developed and given man his wonderful control over natural resources—was established by the ox and the plough. The permanent settlement on the soil was thus an outgrowth of the pastoral stage of society. Man had first to domesticate the wild cattle before he obtained the extra-human source of power necessary to subdue the land to his purpose.

So when man turned to the task of winning his food directly from the earth, the social inequalities of the pastoral age had a profound effect in shaping the conditions of agricultural society. Wealth in those days was actual power, for it consisted of cattle and slaves and servants. Among the things which we in modern times have almost forgotten is the importance of horned cattle, not merely in the infancy of society, but at a period when it had made considerable advance towards civilisation. Nowadays, when we use the word "capital," we mean money, but "capitale" originally signified cattle reckoned by the head. Our own word "chattels" is derived from cattle; and "pecunia," the word for money employed by mankind for the longest time together, comes from "pecus," that means cattle. From Ireland to India the ox has been the original measure of value, and from the number of cattle a man possessed his rank and power were derived and maintained.

Seizure of Tamed Cattle Put Wealth Into the Hands of Chieftains

Horned cattle were, of course, of great importance to man in the pastoral stage of society; they provided him with milk and flesh. In those days the usual means of obtaining an uncommonly large stock of this primitive capital was by a cattle raid, such as forms the subject of the most celebrated piece of ancient Irish literature. There we read how the Queen of Connaught got an army together to rob the King of Ulster of a wonderful bull. Naturally, in these wars of plunder, most of the spoil became the property of the noble classes, whose occupation was war, and who had a monopoly of the profits of office. Thus a profound difference between the rich and the poor already obtained before the tribes and nations settled down on the soil. The means of cultivating the land was in the hands of the chiefs and the nobles, and the poor tribesman often had to borrow from his lord the cattle he needed to plough with.

How Pastoral Wealth Became Landed Wealth When the Ox Superseded the Hoe

The land itself was practically useless. The population was small, and a large estate of rough heath could be had merely by settling on it. Land was a superfluity, but "capital" was extremely perishable, and increased with great difficulty, and lodged in a very few hands. It was the private ownership of the living instruments of tillage that gave a value and a special importance to the possession of the soil. The result was that the men of wealth in

the pastoral age became still more wealthy and powerful in the days when the ox-drawn plough took the place of the hoe devised and used by the women of the tribe.

What is the use of certain fishing rights over some portion of the sea to a man who does not own a boat? Not much more useful was the right to farm a certain portion of ground to a man who had no ox and plough. From the beginning of the agricultural settlement, the chief and the nobles became the largest landowners, by reason of the fact that they had the largest number of cattle. No tribesman grudged them their vast estates. There was a superfluity of mere earth, and a sad lack of the means of cultivating it. On the other hand, it was urgently necessary for the tribe to obtain an abundant supply of food. It enabled them to multiply faster than their enemies, and added in other ways to the warlike strength of the whole group.

It must be remarked that the first races of the agricultural era had to fight their way into a Europe occupied by two races of skilful and daring hunters. It was in the New Stone Age that the struggle began; and though the invading farmers were probably no better warriors than the native hunters, they were able to win by force of numbers. A thousand farmers can exist on a tract of land where only a single hunter is able to get food. So every new piece of ground broken up and tilled added to the resources of the farming races.

How the Rich Cattle-Owner Exchanged Stock for Service

It was thus bad policy for the wealthy chiefs and nobles to keep any cattle which they did not require in working their own estates. Hence arose the custom which seems to be the origin of the manorial system of land-holding. It was in the interests of a chief or noble to attach to his person as many fighting men as possible. With this aim he "gave stock." He gave his men the cattle by means of which they could bring into cultivation their portion of the tribal land, and he exacted in return various kinds of service.

The new position which the tribesman assumed through accepting stock from the chief, varied according to the quantity of cattle he received. The free tenant only took a small amount of stock, and he remained a freeman and retained his tribal rights. In Ireland—the only country of which we have full details of this practice—his tenancy lasted seven years. At the end of that time he became entitled to the cattle which he had received. During the seven years, however, the chief had a right to the milk and manure and the calves, the tribesman only using the cattle for agricultural purposes. The tribesman had also to help in gathering the chief's harvest, and to assist in building the fort. Of course, he was also bound to follow the chief in war.

If a tribesman accepted a large stock of cattle from a chief, he sank to a position resembling that of a base tenant of a manor. He parted with some of his freedom, and his duties became very onerous. He owed a heavy food-rent, which developed in time into a rent paid in respect of the land; and at certain periods, for a fixed number of days, he and his household and his goods were at the disposal of the chief. He was a menial.

The Gathering of Personal Dependants Around the Wealthy Man

So far the system of giving stock did not greatly alter the condition of the ordinary tribesman. It introduced a firmer bond of political union between the chief and his men, and perhaps did much to enable the ruler strongly to exercise authority, without playing on the superstitions of the people as the older wizard chiefs had done. Matters of politics were separated from the practice of magic, and the organisation of the tribe or nation was more lucidly conceived and more thoroughly carried out. But this employment of the early agricultural peoples did not make for the liberty of the subject. The power of the wealthy and successful chief increased at the expense of that of the tribesmen. By giving stock to stragglers from other tribes, and by allotting to them some of the unoccupied waste land, he gathered around himself an army of personal dependants, who were distinct from the tribesmen.

How the Oxen-Drawn Plough Made Slave Labour Profitable

The dependants owed the chief a rent for the land as well as a rent for the stock, and thus they enabled him to increase in wealth and power at the cost of the tribesmen. Probably the tribe became stronger for defence or attack by this addition to the population of the territory, but every strange dependant curtailed the waste land available for common pasture.

But the worst feature of early agricultural society was the fact that the oxen-drawn plough made slave labour profitable. Chiefs and noblemen who were wealthy in cattle now had an additional zest for

warfare. Every prisoner they took was a new source of wealth, for each servile herdsman and ploughman enabled them to enlarge the domains they cultivated themselves. In many parts of Europe, the serfs seem to have had an origin distinct from that of the dominant race. They were probably drawn from the older or aboriginal inhabitants of the country. Families, or subtribes formed out of them, became hewers of wood and drawers of water to the free tribesmen. Others remained in a condition of special servitude to the chief, or became dependent on him. They were either engaged in cultivating his own domains and in herding his cattle, or they were planted by him in separate settlements on the waste land of the tribe. The rent or service which they paid to him for the use of this land appears to have been determined solely by the pleasure of the chief.

The Usefulness of the Ox Expressed in a Religious Dignity by the Hindoos

Thus we see that the history of horned cattle is unhappily mixed up with that of large portions of mankind. The same causes that altered the position of the ox, and turned him into an instrument of agriculture, produced also a great extension of slavery. The sanctification of the ox among Hindoos, rendering his flesh unlawful as food, must have been connected with the desire to preserve him for tillage; and the legal dignity of property in oxen among the Romans appears to answer to their religious dignity among the Hindoos.

At the time when cattle became of the greatest use to man, the struggle between capital and labour began. How long it went on in the New Stone Age we have scarcely any means of knowing, though we can still discern in glimpses some of the large events of those distant days. The earliest of European farming races was the Iberians, who still form a considerable part of our population. They are often called the Mediterranean race, as they are found in large numbers on the southern shores of Europe.

Why the Conquering Celt Spared the Dark Little Iberian

It was they who first peopled Egypt, and laid the foundations of the wonderful agricultural state which arose by the Nile. They spread across France to the British Isles, and possibly erected Stonehenge and the other strange stone circles found in our country. It is also probable that they constructed the wonderful lake village of Glastonbury, though it is very doubtful if they retained possession of it. For though they were a very ingenious people, small in stature, with dark hair and dark eyes, they were not a match in bodily strength for the tall, fair-haired, and blue-eyed Celts—the Irishman and the Welshman—who invaded their territories.

Perhaps in the ordinary way the Iberians would have been wiped out or driven from all the fertile land. They had exterminated the hunters of the Old Stone Age, and they were in turn conquered in the course of time and threatened with destruction. For when the Celt discovered how to make bronze weapons of attack, he carried all before him, and invaded the whole of southern and western Europe, from Greece to Ireland. The Iberian farmer, however, was too useful to be destroyed or chased away, as the ancient hunters had been. So he was reduced to slavery, and attached to the land; and from him are descended many of the serfs of southern Europe and the British Isles. In other cases, a slave population was evolved in warfare. At the same time, many of the free tribesmen lost some of their independence by becoming indebted for cattle to the chiefs and nobles.

How the Bondage of Debt Split Up Early Societies

So at the dawn of history we find some of the chief European races divided into two or three classes. Nearly all the power and wealth are possessed by the noble class, and a considerable number of the commoners have "taken stock," and become the debtors of the superior class. The case of the patricians and the plebeians of early Rome is the best known. At the beginning of Roman history we find the Roman commons in money bondage to the nobility. In the same way, at the beginning of Athenian history, we find the commonalty are the bond-slaves, through debt, of the aristocracy.

These two facts alone are very curious, and many attempts have been made to account for them. The most plausible suggestion is that it was the occurrence of repeated bad seasons which placed the small farmers of the Attic and Roman territories at the mercy of wealthy nobles. But when Julius Cæsar invaded Gaul, he found that even the barbarians of that country were divided into a noble class and a plebeian class; and one principal source was, he says, the number of their debtors. "The people are regarded," Cæsar wrote, "in much the same light as slaves, without any initiative or voice in public affairs; and

many of them are forced by debt, or the pressure of taxation, or even by violence, actually to become the slaves of the more powerful."

A flood of light has been thrown on this remark of Julius Cæsar by the study of the Brehon laws of ancient Ireland. From this study we find that it was "the giving of stock," for the purpose of tillage, which enabled chiefs and nobles to extend their power over the commoners. Very often the gift of cattle was not willingly received; it meant subjection, and the tribesman accepted the cattle only under the threat of violence.

There is, however, another passage in Cæsar's work which has been supposed by some writers to show that among the German tribes, at least, the free village community was an original and general institution. Cæsar conducted an expedition on the right bank of the Rhine that lasted eighteen days, and he remarked on the fact that among the Teutons "there are no separate estates or private boundaries." Cæsar, however, does not show us anything like a communal holding in land, with an association of freemen cultivating in common the soil of which they were the common owners. He describes—and this is a very different thing—the chiefs disposing of the soil of which they alone appear to be the owners, and each year moving families and groups of men from one place to another.

The people seem to have had few rights and little power. For the chiefs left them only as much land as they thought fit, where they thought fit, and forced them to move from place to place. Tacitus also says that the Teutons were divided into a noble class, a class of freedmen, and a class of slaves. The freedmen occupied a position only a little above that of the slaves.

THE STOCKADED HOUSE OF A GERMAN FARMER IN THE MIDDLE AGES

Thus it looks as though the Teutonic noble emerges into the light of history with as much power over the commoners as was possessed by the superior classes in Greece, Rome, and Ireland. It is certain that when the Teutonic races swept from their northern forests on the Roman Empire, and divided the lands they conquered, they had pretty clear ideas about the private ownership of the soil. They

knew nothing about community in land, and they never practised it. For instance, in the year 680, the King of the South Saxons granted to St. Wilfred the peninsula of Selsey, with the persons and property of all its inhabitants, and among these were two hundred and fifty slaves. Nearly all the early grants of land, beginning as early as 674, expressly transfer with the soil the cultivators upon it, who are called serfs. The country was, in fact, divided into domains, belonging to one or more proprietors, and cultivated by more or less servile tenants. This system of land-owning was not confined to England, but obtained in Western Europe.

How the Tribesman Finally Lost His Birthright to a Share of the Common Land

What the free tenants, descended from the free tribesmen, retained was a right over the unoccupied waste land. Down to the fourteenth century in Wales every free tribesman had a birthright in a certain amount of land for grazing and tillage. This birthright, however, could not be sustained when the population had so increased that there was no more waste land to be divided. So long as land was a superfluity, and the ownership of it was to be obtained by any man with a means of cultivating it, there was little or no restriction of the birthrights of the Welsh tribesmen. This fact bears out our view that there was not in the earliest times a common ownership of agricultural land, but only a common opportunity for obtaining individual or family possession of a part of the soil. How much land a man obtained depended on the number of oxen or horses and the number of slaves or dependants he had.

The Feudal War Lord that Stripped the Commoners of Their Ancient Rights over the Waste Lands

On the other hand, there is no ground for the assumption that the primitive lord of the manor had any proprietary interests in the waste lands. No doubt he could give a man leave to settle on part of it, but this was originally for the general benefit of the tribesmen, as it added to their number and to their food resources. But when the tribe was already fairly large, and the waste land had become a valuable common pasturage, the settlement of a stranger under the lord's protection was not regarded with pleasure. The green and pleasant stretches of commons which are still found in many English villages do represent a sort of communal tradition. They come down from the time when every free tribesman had a birthright to annex and cultivate a part of the remaining waste land, the waste land itself being a remnant of the old, free, migrant, hunting and pastoral days.

In England, however, the Norman Conquest robbed the commoners of this vestige of the pastoral ages. For the Norman lawyers gradually created the idea that the common was the lord's waste, and that he had the power to do what he liked with it. The Normans did to the English what the English had done to the Welsh, and what the Welsh had done to the Iberians. Might was right. But even the Iberians could not complain, for their forefathers had dealt still more harshly with the race they conquered.

What the Norman Conquest did was only to develop, in a stern, logical way, that principle of feudalism which had been implicit in the agricultural tribes of Europe ever since the ox was attached to the plough. The hard-headed, businesslike Norman deserved all the profit he made by his rigorous feudal system, for he was an admirable organiser. He stripped the English race of its rags of sentimental and superstitious practices, and placed all matters of politics on a common-sense business footing.

The Beginning of the Struggle for Freedom Between the Lord and the Peasant

In the old days a tribesman was bound to his chief as much by sentiment as by law, for in many cases the chief was regarded as the descendant of a god, for whom an ordinary man would gladly give up his life. Even when, with the spread of Christianity, the ancient superstitions vanished, there remained a passionate loyalty to the leader, in which an unreasoning emotion, inherited from the old pagan days, was of much force. Now, a blind and vehement attachment to the person of a chief is a fine and romantic thing. In some circumstances it makes for efficiency in war. But when a country is split up under a number of chiefs, most of whom are fiercely ambitious, the passionate loyalty of their followers does not conduce to national unity and general political development.

The Norman, with his strong hand and hard mind, forced the English commoners and serfs to look at things as they really were, and fight for their own hand. For hundreds of years they had been drifting into feudalism without looking where they were going. The Norman merely hastened

the progress, and tore from a population of tenants, dependants, and slaves the last of their illusions, and left them to fight their way to freedom.

In the Doomsday Book there are some faint indications that the struggle for liberty had begun. For there seem to have been a few villages in which the lord of the manor had been bought out. As a rule, however, the struggle for freedom and independence began in the large, prosperous towns, where the middle classes, by their wealth and their organisation, were able to resist the forces of feudalism. In the country the tenants of the manor gradually combined to fight against the "giving of stock" by the lord. The villagers adopted a system of co-operation, and began to supply their own carts, ploughs, and harness, and breed their own horses and cattle. In this way they were able to escape from the most degrading forms of servitude. From working together for their lord, they learnt to work together for themselves. As their wealth increased they were able to obtain, first, charters, and then leases; and the best men among them gradually rose into free tenants of the modern sort, and at last into the honourable position of yeoman farmers, possessing free land to the annual value of forty shillings, and entitled to serve on juries and vote for the knight of the shire.

Liberty is a noble and a precious thing. It gives to the race that really wins it a varied and alert power of personal initiative which often does more than any other human force to promote the progress, material and spiritual, on which civilisation depends. But it was not until society was strongly and permanently organised for co-operative purposes that individual freedom became possible. We must not, therefore, continually fancy that there are precedents in the past history of our race for all the advances towards a larger liberty to which we are now working. The village communities of the Middle Ages, for instance, were far from being a pattern for modern imitation. Derived from the rigid organisation of labour on the manor, they made neither for progress in agriculture nor for the personal freedom of the peasantry. We have now to see how the primitive system of common holdings, which largely obtained in our country a hundred years ago, was supplanted by a more efficient system of separate farms, and by scientific tillage.

BODIAM CASTLE, ONE OF THE LAST FEUDAL STRONGHOLDS BUILT IN ENGLAND

ORDERED HOMES OF HEALTH AND BEAUTY

A RESIDENTIAL QUARTER OF LETCHWORTH, SHOWING OPENNESS AND INDIVIDUALITY

GIVING NATURE HER CHANCE—A ROAD IN THE SHOPPING QUARTER OF LETCHWORTH GARDEN CITY

The photographs on these pages are by courtesy of The First Garden City, Limited, Messrs. Cadbury Bros., and Messrs. Lever Bros.

HOME-MAKING FOR THE RACE

The Abolition of Old Slums, the Prevention of New Slums, and the Provision of Houses for Families

THE URGENT NEED FOR GARDEN CITIES

The evidence is now clear that the proper housing of the people is a necessary task. No measure of attention to the heredity of the population, even if our understanding of heredity and our power to apply our knowledge were absolute, would avail to make superfluous the problem of housing. The study of the individual anatomy and physiology of man has shown us elsewhere that his body is unique in its need for external protection. Unless natural eugenics were to aim successfully at breeding some kind of man who needed no protection from rain or cold or light, we must have houses of some kind; and, further, the proper housing of the people, from the eugenic point of view, will be something different from a great many schemes and methods for the provision of housing in which the architects and the administrators have evidently agreed that children are an encumbrance.

The housing we provide must be at least compatible with parenthood; it must be designed not for the individual as a unit, but for the family as a unit. Very far indeed are we from saying that all individuals should not be properly housed; but if things are to be placed in order of their importance, clearly the first need is that we shall provide proper housing wherein parents and children may make those homes of the people which, according to King George, are the sure and firm foundations of national glory.

This subject, as everyone knows, has lately received more attention than ever before. This is, indeed, justified by the study of successive censuses, which shows how the population continues to stream into the towns, where the problem is most serious, and where some four-fifths of our people are now born and live and die.

The Eugenist may argue that this proportion of the population in the towns is morbid and dangerous, and may wish for such a revival in the fundamental industry of making food as would establish or re-establish a healthy peasantry. But he has to take things as they are; and this is to say that housing in towns and cities is the more urgent part of his problem.

It is immensely important that the country-side should be attended to; but, as things stand, it is the great cities that must be attended to first. Slums are at this instant being built in this country, though only the ignorant or brutal, and very few even of such, now dare defend them, and though we are about to spend large sums of money in the fight against consumption, of which the slum is the endemic home. We thus have not only the past to correct, but the present also; and the urgency of the subject cannot be overstated.

It is obvious that, thus looked at, our problem is really part of the great and splendid subject of which Professor Patrick Geddes is the foremost living student, and to which he has given the name of Civics. The writer remembers an occasion on which a questioner at a public meeting asked Professor Geddes whether, as a result of his study, he did not return a verdict against the city. The reply was: "Against Jerusalem and Athens and Rome!" No, indeed; to condemn the city as a whole is to condemn civilisation, which is literally citification.

Our problem, as heirs of all the ages—heirs, above all, of the great cities of the ages—is to learn how to avoid the dangers which must always be involved in great aggregations of human beings. Those aggregations are necessary. The theory of the return to Nature for mankind as a whole is absurd. Our problem is the standing problem of man—to transcend Nature and

yet to recognise the conditions under which we may do so—and the first problem of Civics is obviously this mechanical-practical one of housing. Whatever else we desire and expect of the city, the first necessity is that it shall not destroy the citizen; and no one can say that we have yet built, with one exception, any city that can be acquitted on this fundamental, though merely negative, score.

For practical purposes we may begin by a brief discussion of the two independent streams of tendency which in time will undoubtedly solve the vast problem before us, as it has never yet been solved in the history of civilisation. There is first the voluntary or non-legislative line of progress, very real and already notable in result; and there is also a very creditable record and much more to hope for in the strictly legislative line.

What May be Done in the Villages in the Cause of Health

Let us begin, first, with the voluntary workers, represented by certain splendid employers of labour as pioneers, and later by those who have dared to proceed from the Garden Village to the much more elaborate Garden City.

What can be done at the level of the village is beyond dispute. For the purposes of the present chapter, the writer has just paid a visit to Bournville, a type of the demonstration here referred to; and there may now be quoted a few figures, easily paralleled, no doubt, from a few other places of the kind that exist in this country, but by no means to be paralleled elsewhere.

Thus the death-rate per thousand, as an average for the five years ending 1910, was 5·7 in Bournville, as against 14·6 in England and Wales. The infant mortality, on the average, for the same period, was 62·4 per thousand live births, as compared with 117·4 in England and Wales.

A Startling Contrast Between Bournville and Birmingham Physique in Children

It is not to be supposed that these tremendous contrasts are all to be explained in terms of housing alone. Different qualities of housing and different rates of rent have a selective action, so that the poor specimens of a population tend towards its poorest houses. But the housing conditions are unquestionably primary in producing these contrasts; and this is no less evident if we note the comparison recently made between school children in a slum district of Birmingham and children of the same age who are properly housed a few miles away.

Figures are seldom so eloquent, even to the statistician, as those which must here be quoted. The results were as follows.

WEIGHT—BOYS

	AGE 6	8	10	12 yrs.
Bournville	45·0	52·9	61·6	71·8 lb.
Floodgate Street .	39·0	47·8	56·1	63·2 „

WEIGHT—GIRLS

	AGE 6	8	10	12 yrs.
Bournville	43·5	50·3	62·1	74·7 lb.
Floodgate Street .	39·4	45·6	53·9	65·7 „

HEIGHT—BOYS

	AGE 6	8	10	12 yrs.
Bournville ..	44·1	48·3	51·9	54·8 inches
Floodgate Street .	41·9	46·2	49·6	52·3 „

HEIGHT—GIRLS

	AGE 6	8	10	12 yrs.
Bournville	44·2	48·6	52·1	56·0 inches
Floodgate Street .	41·7	44·8	48·1	53·1 „

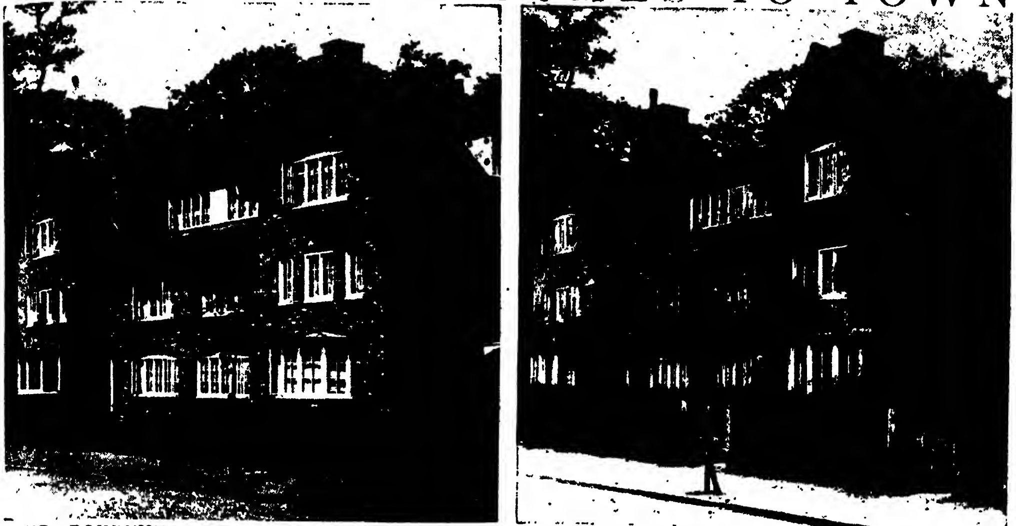
These results are by no means exceptional for the contrast between right and wrong conditions, and they are quoted merely as an example, from a pioneer village, of what a few similar villages are now achieving elsewhere.

But of course a village is neither a town nor a city, and the problem of housing has to be solved on the large scale. Thus, for instance, a population of tens of thousands has shortly to be accommodated in a city, of the deadly or the vital kind, for the purposes of a new naval base in the North; and the question arises whether the experience of a mere village, or any number of villages, is relevant to that problem.

How Garden Cities and Garden Suburbs Everywhere Tell the Same Story of Improved Health

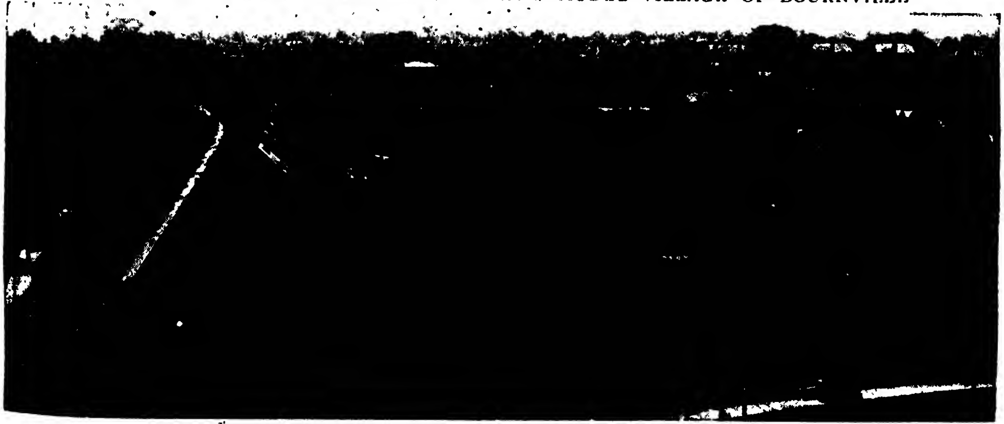
Here we can already answer that. As always in the long run, the idealist is the really practical man. We now have the record of the Garden Cities and Town Planning Association, which is in its fourteenth year of existence, and of which the first-fruits is the Garden City at Letchworth. A brief record of facts may be obtained from the address delivered at the annual meeting in the present year by Mr. Cecil Harmsworth, the Chairman of the Council. There is already a population of six thousand persons at Letchworth, with twenty-eight factories. The vital statistics of Letchworth are incomparably superior to those of any ordinary town, or even health resort, in the United Kingdom. If Letchworth is to be rivalled anywhere, it can only be in Garden Suburbs like that which is already far and away the healthiest part of Hampstead, while Hampstead is the healthiest part of London.

THE COUNTRY COMES TO TOWN



FOUR BOURNVILLE COTTAGES WHEN NEW AND WHEN BEAUTIFIED BY SIX YEARS' GROWTH

A TYPICAL STREET IN MESSRS. CADBURY'S MODEL VILLAGE OF BOURNVILLE



A GENERAL VIEW OF COTTAGE GARDENS AT BOURNVILLE

Each house has about five hundred square yards of garden behind it, and between these gardens, as shown in the centre of the bottom picture, are lines of screening and prolific fruit-trees.

At the present time in this country we have thirty-seven Garden Suburbs, either in actual existence or in course of promotion. So long as existing cities grow and must grow, the method of the Garden Suburb is the right one; but there are many important differences between a Garden City and a Garden Suburb, and those who wish to go furthest forward in this matter must never aim at anything less than the Garden City itself. The case of Rosyth, already alluded to, shows clearly the absolute alternative which is the real problem of the future. Can we there build a Garden City for 30,000 people, or are we to build another of the mortal cities of the present time, with or without Garden Suburbs for the lucky few?

The Work of a Reformer who is a Politician Indeed

The answer to this question was furnished in anticipation by the distinguished pioneer, not the first pioneer of his name, who wrote, not many years ago, the book, "To-morrow," in which the idea of a Garden City, already real at Letchworth, was laid down. Before these words appear, Mr. Ebenezer Howard will have been entertained at a complimentary dinner in London, at which Earl Grey has consented to preside; but it may yet be a generation or two, when probably every politician of the present day is forgotten, before this real politician is honoured, as he should be. If *polis* means a city, and if politics to the Greek was the science of the city, then Mr. Ebenezer Howard is a politician indeed.

"To-morrow," as we have seen, has already become "to-day," but our business now is with the to-morrows to come. We may turn from this brief description of unofficial progress to the recent legislative record, and to an extremely important project of the future. The reader will be good enough to observe that we are above party-political prejudice in our present discussion. There is no room for party politics when we start talking politics.

Making Civilisation Possible—a Problem of Citizenship too Great for Partisan Treatment

We have already alluded impartially to the work of Mr. Cadbury and to Mr. Cecil Harmsworth, and we must now refer to an Act promoted by Mr. John Burns, and thereafter to a Bill which has been drafted, and is being backed, by Unionist members of the present House of Commons. The truth is that few of us at our best are as bad as our party politics, which represents not the citizens of the nation, but the partisan in each citizen.

Our problem is too great for partisanship; it is no less than the problem of making civilisation possible under the conditions of human numbers and human desire in our own and the coming time. Let us therefore preface our survey of what politicians of all parties are proposing to do, with an analysis of the various aspects of the problem, at which our survey of private and philanthropic effort has already hinted. There is an existing problem, and there is the provision for the future, because population incessantly increases. Therefore we require:

(1) *To build new cities from the beginning*, as at Letchworth, and, we hope, at Rosyth, on the Firth of Forth.

(2) *To make "Garden Suburb" extensions to existing cities*, as at Hampstead.

(3) *To provide rural housing*, chiefly, but not wholly, in the form of Garden Villages.

(4) *To destroy* and replace existing accommodation unfit for human habitation (*a*) in the cities; (*b*) in the country.

These are substantially the headings under which the problem of housing is to be discussed at the second National Conference on the Prevention of Destitution, to be held in London in June of the present year; and readers of this section who can do so would be well advised to attend the sittings, at which the subject of housing is to be dealt with under these heads by the best authorities of our day.

The Housing Problem from the Standpoints of Woman and the Home

The various needs have only to be looked at together, and thought over, for anyone to see what a complicated problem this is, and how easily it may be mishandled, as when authorities have forgotten that "nothing is destroyed until it is replaced," which is as true of a slum as of a religion, and have pulled down in one place, only to see the same evils immediately and necessarily occur elsewhere. Further, from first to last the problem has to be solved in terms not of single life, but family life and parenthood. Architects and builders are men who look at housing from a man's point of view: but the problem before us is to build not merely houses but the material outworks of homes, of which woman was the original inventor. Nor is there any chance of supplying our land with houses that women can best turn into homes, which is what the Eugenist demands, until women, who know what grates and cupboards and stairs and taps count for, are consulted in this matter. If anything has a woman's point of view, it is this housing question, which is the material level of the higher question of home-making.

ARTISTIC HOMES WITHIN REACH OF ALL

A PICTURESQUE BLOCK OF THREE WORKMEN'S COTTAGES IN PORT SUNLIGHT

A STREET IN PORT SUNLIGHT, LOOKING TOWARDS THE CO-PARTNERSHIP CLUB

Now let us see what official and legislative effort are performing and promoting, and let us look at the facts in the light of the categories we have already laid down.

First in recent history comes the Housing and Town Planning Act, of which Mr. John Burns was the efficient promoter. Mr. Cecil Harmsworth has expressed the opinion that "when the record of recent legislation comes to be examined in the future, it will be almost universally recognised that this was the greatest measure of legislation of our time." According to the most recent return as to the working of this Act, the Local Government Board had given authority to prepare schemes in ten cases; notices had been given to twelve local authorities; schemes had been devised in many districts, and there were also under consideration thirty-four more schemes, most of which would undoubtedly come to fruition. Of course, it is early days yet in which to express any considered opinion as to the working and future of this Act. At least, the impartial observer, looking from the sociological standpoint, may hail it as a necessary and invaluable step towards the evolution of a really adequate and national solution of what is essentially a national and not a local problem—if we are a nation at all.

Town Planning and an Act for Standardising the Conscience of the Nation

But before we leave this Act—which, after all, is only a matter of history for the ever-forward-looking Eugenist—let us repeat that not the least of its services may be the moral compulsion which its presence on the statute-book brings to bear upon administrators at the present time. Informed and educated public opinion is entitled to refer to this Act as standardising the legislative conscience of the nation at the present time, and to say that, in the face of it, the nation cannot permit apathy, convention, vested interests, local jealousy, or any other evil thing, to build a city of the old type for the men and women and children who will have to live and die and be born at Rosyth, in connection with the naval defences of our shores.

If this were a matter of the calibre of a gun or the thickness of armour plate, the papers and Parliament would be full of it; yet who could not show that the health and vigour and efficiency of the forthcoming population of Rosyth are just as vital to the essential purpose of a navy as anything in the structure of the ships? Consider only the proved statistical correlation between bad housing and alcoholism, and no further argument is needed, even for those who have forgotten the German Emperor's recent opinion that the victory in the naval wars of the future will go to the sober side, as it did under Togo in the Far East a few years ago. The reader must pardon our recurrence to this particular question of Rosyth, but the writer would be false to a great opportunity if he did not insist upon it, before such an audience as he now has, and did not do his best to support Professor Geddes at this most critical time, when the administrative decision is to be taken, for good or for evil, and when the weight of public opinion may turn the scale.

How Delhi Affords a Chance for City-Building on a Great Scale

Similarly, the Housing and Town Planning Act must be acknowledged, even by those who demand far more, as a great legislative argument for right administration, in the treatment of the extraordinary and unprecedented problem which has just arisen for our solution in India, where one of the most ancient of cities is to be made a capital centre for the growth of a new and incalculable form of civilisation, born of the fertilisation of the Orient by the West. City planning, on a great scale, and under conditions which can have had no parallel since conquerors built cities for civilisations of which even the names are forgotten, is to be called upon to build and rebuild Delhi to enable it to discharge the stupendous functions allotted to it.

Those who know anything of the terrible tale of duty undone in India, and the consequent ravages of such diseases as plague, which is now known to be essentially a housing problem, dependent upon the control of the rat, will realise what kind of responsibility now devolves upon the Home Government in regard to Delhi.

The More-than-Amateur Efforts at Housing now Promised in Parliament

But there is much reason to believe that, just because the Housing and Town Planning Act is on the statute-book, administrators will be compelled, by the new standard which legislation has erected for them, to do their duty at this unprecedented juncture. And now for Acts to come.

That the future is not without promise is proved by the reference to a Committee of the recently introduced "Bill for the better application and enforcement of the Housing of the Working Classes Acts." This Bill, which passed its second reading (March, 1912) without a party

division, is entitled to the careful attention even of those who know only too well what amateur legislation in such complicated social problems is apt to be. Drafted by a sub-committee of the Unionist Social Reform Committee, it was introduced by Sir A. Griffith Boscawen, who was for close on two years chairman of the Housing Committee of the London County Council; and among those who worked with him in the preparation of the Bill was Colonel Kyffin-Taylor, who is Chairman of the Liverpool Housing Committee. The Liverpool Committee are at present carrying out, under their chairman's direction, an important slum-clearing project; while during Sir A. Griffith Boscawen's chairmanship of the London County Council Housing Committee the biggest slum-clearance scheme of modern times was initiated in London—the Tabard Street scheme in Southwark. This, therefore, should surely be more than amateur legislation.

The Need for Expert Supervision of the Housing Allowed by Local Authorities

The outstanding virtue of the Bill, from the standpoint of the Eugenist, who conceives of the nation as a whole, is its assumption that the clearing of slums is a matter of such vital import to the community, and also so costly a matter, that it cannot and should not be left entirely to local authorities. The Bill demands the active assistance of the State, proposing the appointment by the Local Government Board of three Housing Commissioners, and an annual Parliamentary grant of half a million pounds in aid of housing—a quarter of a Dreadnought per annum for housing—on the analogy of the funds spent by the Road Board in aid of road improvement.

The supporters of the Bill argue, in relation to this expenditure, that to clear slums is to attack the breeding-place of disease, and thus to prevent those ills which we are now to spend large sums of money in the attempt, usually vain, to cure. It is further proposed that one of the Housing Commissioners should possess the qualifications of a medical officer of health; that another should have had large experience in urban areas and the practical development and administration of working-class dwellings; and the third a similar experience in rural areas. These Commissioners would be employed by the Local Government Board exclusively in the supervision of the operations of local authorities under the Housing Acts; they would co-ordinate the work of the various officers of the Board already employed in the work, assist local authorities by advice and information, and make an annual special report to Parliament on housing matters. Everyone interested in this subject knows only too well that local authorities are largely to blame for not doing their duty, as the existing state of the law permits or requires.

Slum Clearance a Duty of the Central Government if Local Authorities Neglect it

Expense is the primary consideration, only very few among us knowing what is the expense of the disease which this "saving of expense" breeds. The Treasury grant proposed in the new Housing Bill would help to overcome this difficulty, and would supplement the influence upon public opinion which the revelation made by the Insurance Act, of the cost of disease, will surely wield. At present the Local Government Board has no effective power of compelling local authorities. The existing law is so entirely idiotic as to give the Board a power which means, in the last resort, putting the local council in gaol—which is no power at all. To overcome this difficulty the Bill proposes a plan similar to that adopted in the case of defaulting education authorities. Under this plan, if a local authority refused to carry out an order under the Housing Acts of the Local Government Board, the Board *would have the power to appoint people to execute the slum clearances desired, and to charge the cost to the local authority.*

We need not here consider other aspects of the Bill. The point for us is that it directly meets two needs which are imperative for eugenics—needs which were never so urgent as to-day, with urban influx, and needs which no legislation hitherto has availed to meet. The Bill would directly lead to the abolition of existing slums, and it would prevent the making of new slums.

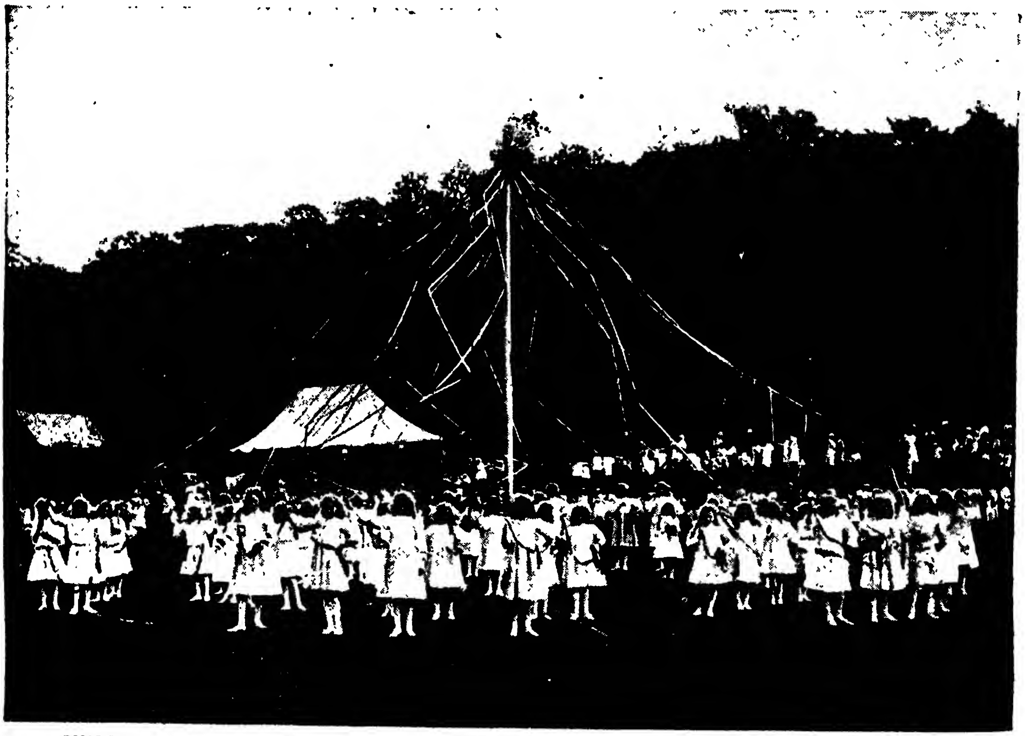
The Acute National Problem of Housing Capable of a Complete Solution

As to the urgent need for some such measure, on these two grounds, there can be no doubt whatever in the minds of those who have some first-hand acquaintance with the problem. The provisions of the Insurance Act, whereby local authorities may be brought to book for the presence of slums which are responsible for "excessive sickness," are doubtless excellent in principle, but they will certainly prove inadequate—a mere expression of good opinion. The problem of housing is a constructive and positive as well as a destructive

and negative one—the population of these islands increases by something like four hundred thousand every year, even if there were not the requirements of those displaced from demolished slums to consider. In this connection we may briefly note that the Housing Bill, as at present drafted, contains clauses which would enable the Treasury to aid local authorities in those cases, frequently illustrated, especially in rural districts, where the sudden development of an industry, such as fruit farming or the establishment of industrial works, leads to acute "house hunger," which local resources cannot meet with due regard to hygiene and the rents the people can pay.

If, now, the reader will compare our outline of the proposals of even this Bill with those four parts of the practical problem of good housing which we prefaced our discussion of the Bill by defining, it will be seen how very far the reformer is from obtaining what the eugenic needs of this country demand. Much greater public and political interest must be created in this fundamental national problem, which every day makes more acute, and is certainly capable of complete solution with a mere fraction of the will and brains that are put into a thousand individual concerns.

Here, then, our present study of nurtural or secondary eugenics is completed. We have traced the nurture of the new lives from conception to maturity, and the prospect of parenthood on their part, and have concluded by discussing the provision of houses in which the new families may find homes. And now we proceed to the vastly more difficult, though possibly more interesting and novel, problems of Natural or Primary Eugenics, under the various categories described in our first chapter. For when our survey of nurture is completed, and when we have acknowledged the immeasurable difference between good and bad nurture of whatever natural material, we are still forced to realise that the complete satisfaction of all our demands of nurture, say in the case of a feeble-minded child, would not completely satisfy the Eugenist or anyone else. We are therefore forced to inquire into differences of "Nature" and the possibilities of controlling them. But this inquiry can only be successfully prosecuted on the multiple and complicated foundations furnished by many sciences; and we must preface our account of it by a brief survey of those foundations—which will not now be quite unfamiliar to students of other sections of this work.



CHILD-LIFE IN A MODEL VILLAGE—A PROMISE OF WHAT WILL BE EVERYWHERE

SECRET OF THE SUN'S POWER

Whence Does the Sun Derive the Energy so Prodigally Dispersed Through Space?

THE ONE SAFE ANSWER GIVEN BY SCIENCE

Having some idea of the great measurements of the sun, and having studied in outline the sun's significance for the earth, we have to plunge—for mind can go where body cannot follow—into the sun's depths, in the attempt to discover the nature and constitution whereby this mighty globe is enabled to do its radiant deeds.

The older way of stating the first problem that confronts us would be to ask the source of the sun's heat. But in these days we can no longer isolate such an entity as heat, for we have the idea of energy, we have begun to "think electrically," and we know that this problem of the sun's heat is simply part of the real question. The sun produces electrical energy—which we call heat, light, etc.—in quantities that are certainly huge. What is their source? We accept the doctrine of the conservation of energy, and we know that there must be a source, and that one of two things is sure—either the sun is only reflecting, so to say, energy of some kind which it is constantly receiving from without, or else the sun is spending its capital of energy, and must some day—only that "day" will be sunless night—become bankrupt. The first point to decide is the magnitude of the facts which we must somehow explain. How much energy does the sun produce?

Here is a question which can, to some extent, be much more satisfactorily answered than the older one—how hot is the sun? For we can definitely measure the energy of some of the sun's radiations, especially those which we call heat; and though we shall always fail, in our experiments, to do justice to the sun, since so much of its energy never reaches our instruments, and since so much more cannot be recorded by them, yet we can positively state that the sun's energy cannot amount to less than a certain figure.

Some idea of it may be obtained by an illustration, the mere numbers being quite useless when they are so huge. We may confine our observation to the sun's heat alone, only a part of the whole, and may consider the celebrated estimate made by Sir John Herschel. That great son of a greater father reckoned that if a mighty glacier, a cylinder of ice forty-five miles in thickness, were to rush into the sun *at the speed of light*, so that not far short of two hundred thousand miles of this colossal cylinder of ice were shot into the sun in every second of time, the sun's heat would suffice to melt it as it came. Considering, again, only the heat of the sun, we may reckon that every square foot of its surface produces as much heat in twenty-four hours as would be produced by the burning of sixteen tons of coal; and a few acres of the sun's surface would comfortably replace all the energy-converting machinery—steam and oil and what not—on our planet.

Another way of trying to appreciate what our minds really cannot appreciate is to think of the heat and light which we feel, and the consequences of which upon our planet we see, and then to ask ourselves how much of the sun's energy comes our way at all. The result is startling. The earth is more than ninety-three millions of miles away from the centre of energy which is pouring its resources into space *equally in all directions*. The heat and light which strike the surface of our bodies, so that we cannot endure them, perhaps, or the heat and light which strike the entire surface of our earth—a mere pellet of matter placed at this tremendous distance from the sun—these are so minute a fraction of the energy the sun is radiating everywhere that no figures can express its

minuteness. All the planets and their moons together, as they revolve round the sun, cannot possibly intercept between them anything but an inconceivably trivial fraction of its energy. All the rest flies onwards into infinite space. We know that it cannot be destroyed. What becomes of it no man has yet begun to conceive.

What, then, is the source of this colossal and apparently inexhaustible expenditure of power? Astronomy asks no more important question, and that for two distinct reasons, of which the first will suffice for the present.

How We Live by a Trifling Fraction of the Bounty of the Sun

We live by the bounty of the sun—by an infinitesimal fraction of his bounty, the greater part even of that trifling fraction being wasted by us. But the expenditure goes on; and even if we wisely employed all the energy that falls upon the earth, all the rest flies past it in all directions, for ever useless to us. How long can this unparalleled extravagance last? We need only the merest crumbs, but if the spendthrift goes bankrupt even the crumbs will cease. The destiny of the human race appears to be at stake. The writer is careful to use the words "appears to be," because new considerations must now be taken into account, to which writers of the past have not been able to refer. But, undoubtedly, if man were never to be more able to avail himself of certain "new" sources of energy—within the atoms of the earth—than he is at present, the fate of the race would absolutely depend upon the continuance of the sun's expenditure, by which almost wholly we now live, and all our predecessors have lived.

The height of the sun's temperature excludes the possibility that that temperature is maintained by combustion, as we have already seen. But there is another argument, under this head, which is even more convincing.

The Continuance of the Sun's Heat Inconsistent with Any Process of Combustion

Let us assume that chemical combination of the type called combustion or oxidation is possible in the sun, that this stupendous sphere is made of solid coal throughout, and that the coal has an atmosphere of pure oxygen to burn in. Even so, a few thousands of years would see the end of its resources. In a word, combustion is impossible in the sun, and no combustion conceivable could maintain the sun's expenditure of energy. No *ordinary* chemical processes of any kind can explain the facts. The fatal objection of time would dispose of the combustion theory, even if combustion were possible; and it equally disposes of the view that the sun is simply a huge hot body radiating heat, as a red-hot globe of iron would, a body so huge that its radiation can continue for a very long time. Calculations can readily be made to test the possibility of this view. They show, just as the calculations of combustion show, that such an explanation would only suffice for a few thousands of years.

These two theories, and the objection to them, prompt us to ask a new question, the answer to which will contribute to the solution of our problem. *How long* has the sun been spending energy in the prodigal manner we have described? Would not a few thousands of years, as in the chronological scale that is still most unwarrantably printed in many Bibles, cover the past of the sun? And may we not expect that a few more will see the end of the sun's brightness and our race? Here every kind of evidence, astronomical, geological, biological, assures us that the sun must have been expending tremendous quantities of energy for not thousands, nor millions, but at least hundreds of millions of years.

Our Ignorance of Whether the Sun's Temperature Is or Is Not Declining

Whatever we can infer from the records of the earth's past, we certainly have no evidence whatever that the sun has been cooling throughout the traceable period of the history of the earth's crust. This is not so say that the sun is not cooling. No man yet knows whether the sun is cooling, though that is probable, or whether its temperature is stationary as a whole, or whether the sun is actually getting hotter. Only, we are absolutely certain that the earth has received intensely powerful solar radiations for periods which can only be guessed at in hundreds of millions of years. When we consider this factor of *time*, together with the factor of *quantity*, we see that the source of the sun's energy must be very copious—beyond our language to compass.

Yet these arguments carry us nearer to our goal. If the quantity to be accounted for, and the time during which it is to be accounted for, are so great, we can definitely assert that the sun's heat is being evolved by transformation of something wholly different, "as the great ages onward roll." No original store of heat, as in the supposed case of the red-hot globe of iron, and no

production of heat from the chemical energy which is liberated by combustion, could imaginably account for the scale of production.

Baffled in this unmistakable fashion, we may turn in another direction. Perhaps the sun is always receiving from without some source of energy which replenishes it —perhaps the furnace is being stoked, so to say, and the source of its energy is not stored within it at all. Now, what is there that pours into the sun, and might thus recruit its energy ? In other words, granted that we cannot account for the sun's expenditure in terms of the sun's capital, *so far as we have gone*, what income may the sun be in receipt of, which we had overlooked ?

Does the Sun Receive an Income of Heat From the Starlight and Starheat of Space?

The sun *does* receive an income from two sources, one immaterial and the other material, and each of these has received very careful discussion in the attempt to account for the sun's expenditure. First, there is the sun's income of starlight; and second, its income of meteorites. As regards the first, we may be brief. The sun is, on the average, just as distant from the stars as we are. We may then estimate the energy of the starlight and starheat which fall upon the earth, may try to allow for the quantity that is absorbed by the atmosphere, and is not registered by our instruments at the bottom of that great ocean of air, and then we may multiply this quantity by the figure which represents the ratio of the sun's surface to the earth's. The larger surface will catch more energy, of course. The result is hopelessly inadequate; the stellar energy thus received does not begin to account for the solar energy. But the inquiry was worth making, for it reminds us of one of the great unsolved problems of astronomy: what becomes of all the energy which the sun and the other stars radiate into space, past their planets, if they have any ?

Is the Sun Fed by Constant Showers of Meteorites Drawn to It?

The second source of solar income is much more important, and our interest in it to-day is much greater, because of the prominence which the meteoritic theory of the solar system has lately assumed in the speculations of such contemporary astronomers as Sir Norman Lockyer, Professor Lowell, and Professor Bickerton. More and more we incline to the view that the "fiery clash of meteorites," their collision and coalescence, converting their motion or much of it, into heat, is the source of the internal heat of such bodies as the earth, and of the sun, which we incline to think of as only a bigger brother of the earth. And if we are to accept, or even to entertain, this new view of the origin of the sun, and of the original heating of the sun, may it not be that, even now, as for ages past, the sun is being fed and increased by a supply of meteorites, the energy of whose motion is converted into the energy continuously spent by the sun ?

We know that our small earth is yet massive enough to attract an unceasing shower of meteorites, whose energy of motion, when they strike our atmosphere, produces the light and heat of what we still speak of as "shooting stars." The sun's attraction is vastly greater than the earth's; and many meteors must surely fall into the sun, and the arrest of their motion must mean that their energy is changed into those forms—electrical, as we now know—which are called light and heat. Yet it is very hard to believe that there can be much meteoritic matter still anywhere in the neighbourhood of the sun, for surely the enormous force of the sun's gravitation would have cleared the space around it of meteorites long ago. The whole problem is one of quantity. Doubtless meteorites still fall into the sun, and supply the sun with energy, but *how much* ?

The Weight of Meteors Needed to Keep Up the Sun's Heat for a Year

We can measure, without much difficulty, the quantity of matter that must be continually falling into the sun if this is the real source of the solar energy. Thus it has been calculated that if we were to grind the moon into fragments like meteorites, and feed the sun with them, they would maintain his radiation for something like a year. That does not take us very far. Let us make a stride in our illustration, and suppose that all the planets together were to be poured into the sun. Calculation shows that, even so, less than merely fifty thousand years would see the end of the energy thus supplied.

Such calculations answer our question only too conclusively. The sun would need to catch "a moon-weight of meteors" every year to keep him going; and we can definitely say that the necessary supply of meteors is simply not to be had. We should know about it to our cost if the space of the solar system were so crowded with roaming meteoric matter as would be required to

satisfy the sun's needs in this way. Besides, not only our own experience but the experience of Mercury is conclusive. If there were anything like the necessary proportion of matter moving in the neighbourhood of the sun to supply him with an adequate income, Mercury would be disturbed gravitationally to an extent which, we can definitely state, does not occur. No doubt a meteoric supply must exist for the sun's energy, but it is hopelessly inadequate to explain the rate of expenditure; and the suggested explanation is no better than its predecessors if it hopelessly fails, as they have done, on the score of quantity.

Will the Shrinkage of the Sun Account For Its Output of Energy?

We are thrown back, then, on the sun itself. Its source of income must be from within, after all, hard pressed though we may be to find it. And the case of the meteors, impelled by gravitation, gives us a clue. The mutual gravitation of the particles composing the sun must involve collisions and heating, and this may be the source of the sun's energy. Here is a simple but colossal idea which has been discussed and examined by the greatest astronomers and mathematicians for many decades, and can be supported by a great deal of evidence. Just as the possible explanation from the meteorites at once reminded us of the meteoritic theory of the origin of the solar system, so we are now reminded of the original nebular theory of Laplace. Since his day, such minds as those of Herschel, Helmholtz, Kelvin, and Newcomb have devoted their best powers to the subject. Nor need we depend upon any such theory as Laplace's. Whatever the origin of the sun and the solar system, we can deal directly with the question: does the sun contract? And with the further question: can any possible shrinkage of the sun account for his output of energy?

How Long Heat from Shrinkage Would Keep the Sun Alive

We cannot actually observe any contraction of the sun. If modern methods had existed in antiquity, and we could compare our records with those of, say, two thousand years ago, possibly something might be learnt. Our successors will be better off in this respect. But though we cannot appeal to actual observation, we may be sure that the sun is contracting, and is thereby producing energy. And, just as in every one of the possibilities already examined, only to be rejected, we have merely to ask one more question, but that is a crucial one: how long would the sun's contraction maintain its expenditure of energy? The answer to this question has been accounted satisfactory until very recent years, and for a very considerable time. Thus, Sir Robert Ball, writing in 1886, could accept the contraction theory in these words: "It is one of the achievements of modern science to have effected the solution of the problem—to have shown how it is that, notwithstanding the stupendous radiation, the sun still maintains its temperature."

And there the answer to the great problem remained until our own century. Once again, however, we find that the twentieth century is opening out new realms of knowledge undreamt of by the best wisdom of the most recent past; and the accepted theory of the sun's energy must now be revised in the light of our new knowledge.

Revision is necessary, because when the test of time, which has been fatal to all our other theories, is applied to this one, it breaks down too. Certainly it stands the test far longer than any of the others did. The best of them would only avail for a few thousands of years, but this would avail for some millions.

The Hopeless Inadequacy of Shrinkage to Account for the Sun's Career

Sir Robert Ball, who has devoted very special research to this subject, returned to it in his lectures at the Royal Institution, early in the present century. At that time there was much more to be said in favour of the gaseous-nebula theory of the solar system, as described in Chapter 10, than we can now accept. It seemed quite legitimate to assume that the sun is the shrunken concentration of a mighty nebula—the "solar nebula"—which once extended as far as the orbit of Neptune; and calculations are possible which afford us some idea of the energy such a nebula would contain—energy which, by the gravitational contraction of the nebula, might be transmuted into the energy of the present sun, that we feel and see. Of course, there is no certainty in all the *data* whereupon these calculations are based. But still we know enough to afford us some measure of the possibilities; and the result is that we find ourselves with an explanation of the sun's energy that may avail for, perhaps, four, six, ten, twenty-five millions of years. These figures are far enough apart, no doubt, yet we may take the largest or the

smallest, and the verdict on it is just the same—it is hopelessly inadequate.

These estimates are, indeed, far more evidently inadequate now than they were only seven or eight years ago, when men of science were still quoting Lord Kelvin's guesses at the age of the earth and the sun. Those guesses varied widely among themselves at different times, according to the various assumptions on which Lord Kelvin based them, and they are now of nothing but historical interest. Still, we may note that one hundred millions was a figure which Lord Kelvin gave at one time—too high, we observe, to be accounted for by the contraction theory of the sun's energy, as estimated above. But modern work has taught us that all these nineteenth century guesses—more usually, to tell the truth, stated as positive results of knowledge—were far short of the truth. So much the worse, today, for the contraction theory of the sun's energy.

Where Action Between Atoms Fails, May Not Action Within Atoms Succeed?

The reader who remembers a very early chapter in this section will already have asked himself a question which occurred to men of science all over the world a few years ago. Everything hitherto has failed us—the radiation of a very hot and very large body; combustion or any other form of chemical action hitherto recognised; the reflection of starlight; maintenance by meteorites; even gravitational contraction. But all the while there was a source of energy, immeasurably greater than any we had thought of, which was perfectly available, but of which we did not even know the existence. We were still thinking of the atoms of the sun as tiny, hard, inert things, which went where they were pushed or pulled, and could only give expression to energy, energy of motion, chemical energy, or what not, that somehow existed outside them. Chemical action was out of the question at a temperature like the sun's; and by chemical action we meant (and still mean, though indeed knowledge has outrun language) the action *between* atoms. The idea of action *within* atoms was to be counted an absurdity.

The Discoveries Respecting Radium Suggest a Solar Output of Energy Immeasurably Long

But radium the revealer has altered all that. The Polish pioneers, probing pitchblende in Paris, found in that heavy, black, dull mineral, dug from the dark bowels of the earth, the secret of the sun in his strength. For in pitchblende they found radium, and radium is an element composed of atoms which explode, *giving off energy*. This is not "chemical action," as we had understood it, but it reduces all the chemical action ever dreamt of to a mere negligible trifle. It is as if by far the greater part of all the energy of the universe had been used up in building atoms, and only a trifle had been left over for use outside them. Now, the explosions of radium atoms, dispersing the energy which was used—how, where, when, by whom?—when they were made, are unaffected by such trifling considerations as the difference between the temperature of frozen air and that of the electric furnace, though that is difference enough to affect profoundly all the ordinary chemical operations we know. The atom evolves as it will, because it is what it is; and if there were radium atoms in the sun, we are quite sure that the temperature of the sun would not interfere with their production of energy.

"Is the sun made of radium?" was a question put by many amateurs of science. Certainly not, the student could reply, for, if it were, we should not be here. But if there were in the sun a most ridiculously small proportion of radium, a proportion even so small that perhaps we could not detect it, *that* might yet be sufficient to account for all the solar output of electrical energy, for almost as long a time as anyone might care to name.

The Presence of Helium in the Sun a Suggestion that Radium is There

It is rather as if a number of thirsty men had been trying to make a saucerful of water go as far as possible, and had suddenly discovered that they were afloat upon Lake Superior, and might drink almost for ever without fear, so gigantic is the revelation of unsuspected resources which one glance within the atom reveals. Hence, it would appear, we must set ourselves to the question of determining whether there is radium in the sun.

Every probability points in that direction. Numerous other elements, as we shall see later, are found in the sun and in the earth. We believe that the sun and the earth are of common origin. The wonderful element helium, first discovered in the sun, by Sir Norman Lockyer, as far back as 1868, and christened by him accordingly, identified in and prepared from the earthly mineral cleveite by Sir William Ramsay in 1895, is now known to be one of the products of the decomposition or evolution of the atom of radium. The presence of helium in the

sun is therefore a most striking piece of evidence in favour of the view that radium must be there, too. But, of course, that is not conclusive evidence, and we are bound to look for direct demonstration of the presence of radium in the sun. We must do so, however, with very moderate expectations. Radium is an exceedingly scarce constituent of the crust of the earth. It *must* be an exceedingly scarce constituent of the sun, if it be present there at all, for the simple reason that otherwise the sun would be far hotter than it is. The study of the spectrum of the sun, in order to detect evidence of radium, was practically the last piece of work undertaken by the veteran pioneer of spectroscopy, the late Sir William Huggins, and by his distinguished wife. But we cannot at present regard the results as conclusive.

Radio-Activity in the Sun the Probable Secret of Its Energy

We need not, however, be disconcerted at this, for we have been assuming that only radium can supply us with atoms capable of evolving energy from their interiors. But radio-activity is in all probability a general phenomenon of matter. Many radio-active elements besides radium are now known; and we have every reason to believe that, if we find some elements not radio-active, the simple reason is that we have not observed them for, say, half a million years or more. Every kind of atom has its own characteristic rate of evolution, just as the individuals of any living species have a particular and characteristic longevity—that is all. Thus our decision as to this new theory of the sun's energy does not hang upon the demonstration of radium or of any other one element in the sun. That the sun is radio-active is no longer disputable. Modern study of atmospheric phenomena is beginning to teach us that, for instance, the aurora borealis is a consequence of the sun's radio-activity. And once the radio-activity of the sun is proved, the secret of his energy is out.

The Vast Expansion of Modern Ideas Owing to the Discovery of Intra-Atomic Energy

This, of course, is not to say that the other explanations, already discussed, do not contribute—in their little degree—to the sun's resources. But the discovery of radio-activity has itself compelled us enormously to extend our time-scale of the solar system, and therefore of the expenditure of the sun; and only the discovery of the intra-atomic energy, of which radio-activity is now proved to be the expression, will suffice at all for the demands made upon the sun by our modern ideas of the length of the past during which his expenditure has been maintained.

We are here at the very limits and outposts of human knowledge. To be more detailed or more dogmatic would be to court inaccuracy. But we are already sure enough of the essential facts for us to see that they are the basis for a newer and deeper interpretation of the skies and their phenomena than anything of which the past could dream—newer and deeper not at all in the sense of superseding or annulling the gravitational and telescopic astronomy of our predecessors, to whom we are indispensably indebted. The second half of a pair of scissors is worth no more than the first, but rather more than doubles its usefulness. So here we feel that the addition of the theory of radio-activity to the knowledge bequeathed us by the nineteenth century gives us a complete instrument, with complementary halves, which will cut the veil of ignorance in twain.

Early in this chapter it was said that astronomy asks no more important question than that of the sun's source of energy, for two distinct reasons, the first of which was that the sun matters so much for mankind.

The Story of the Sun as an Introduction to the Study of the Problem of Starlight

The second reason was not stated. It is that the sun is a star, and that any really valid answer to this question as regards the sun, our star, throws sunlight indeed upon the dim and distant problem of starlight! Of all the millions of stars there is just one which is placed beside us. If ever we are to understand them, in their all but infinite remoteness, it will be by our study of the one example which we can almost handle—an assertion not too strong if we remember how the modern astronomer, in his laboratory, can pull sunlight to pieces to see what it is made of. Hence our study of the sun is necessarily, in large degree, a study of all the stars.

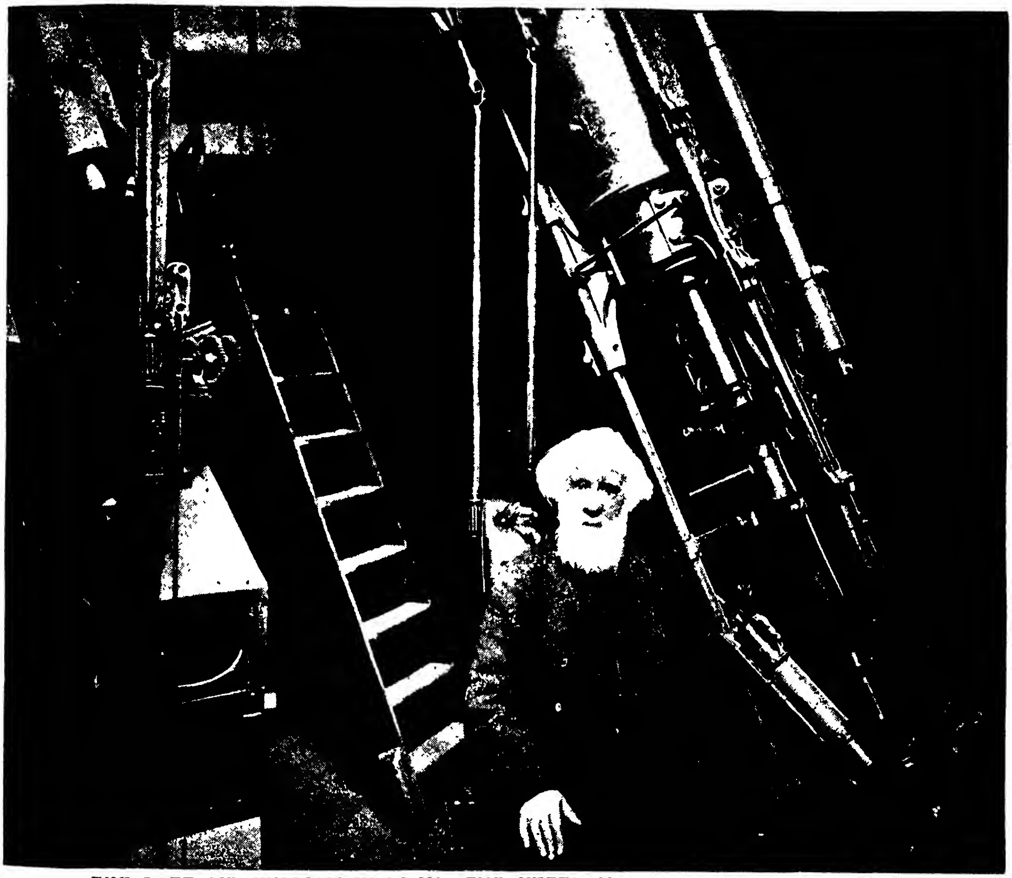
This new development illustrates yet again the profound remark of Herbert Spencer that the greater the growth of the sphere of knowledge the greater is its area of contact with the unknown. Everything must now be revised. All manner of conclusions, based upon the view that only such and such forces had to be reckoned with, must be restated after we have tried to reckon in radio-activity as well. In the case of the stars and nebulæ this will be a very long and difficult task. The first step towards its

fulfilment is to learn all we can regarding the condition of sunlight. The curious fact is that we see far more deeply into the sun when we look at its light than when we look at it by its light. Hence the modern study of the sun is above all spectroscopic, but to the spectroscope we must add all the imaginable apparatus which will help us to determine, from the sun's light, the facts of its radio-activity.

With this key we shall hope to interpret the stars, in some degree. But we must beware of supposing that, *this time*, we have got final methods, final instruments, final results. That is what the nineteenth century was always thinking. In the face of radio-activity we realise that all the astronomical work done hitherto is little more than a preliminary survey of the field! But radio-activity occupies, for us, just the place that the law of the conservation of energy did in the middle of the nineteenth century, and the law of gravitation a few generations before. Each in its turn was thought to be the key to all things. But that is not the true history of human knowledge. Each key that is to unlock all things is discovered, in the long run, to be chiefly valuable because, on using it, we find ourselves possessed of a new key, demanding to be used in its turn.

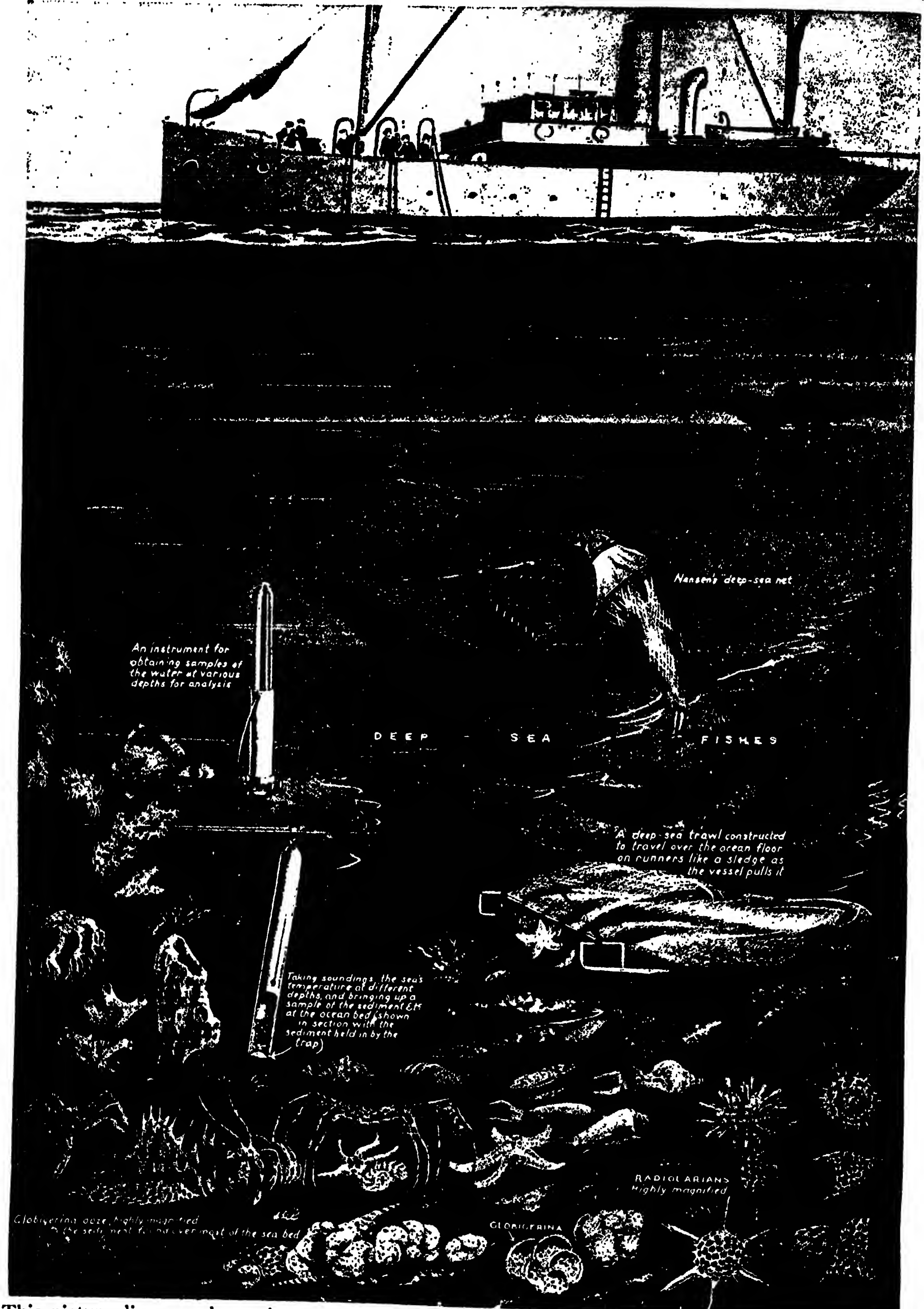
That will be the case here also. Radio-activity is the new key which we must use. All the available forces of the human mind are now engaged in the task of turning that key in the lock upon the gates of darkness. New knowledge will be revealed—a new understanding of the secret of the sun. But that secret holds a secret. Perhaps it may be the understanding of the nature of gravitation, knowledge which would be power indeed.

Meanwhile, our task is to investigate the minutest details of the sun's chemistry and physics and magnetism with all the care imaginable, realising that we are thus, in some degree, examining all the stars, and laying wider yet the foundations of that temple of truth in which the soul of man to-come, long years hence, shall worship the source of truth and of men.



THE LATE SIR WILLIAM HUGGINS, THE VETERAN PIONEER OF SPECTROSCOPY

IN THE DEPTHS OF THE ATLANTIC OCEAN



This picture-diagram shows, in an exaggerated manner for the sake of clearness, the methods by which scientists explore the depths of the oceans and bring up various forms of life and deposits. The vessel represented is the "Michael Sars," which was sent out into the North Atlantic in the spring of 1910 to continue the earlier work of H.M.S. "Challenger."

ROMANCE OF THE SEA-BEDS

Does the Great Pacific Ocean Fill a Huge Rent From Which the Moon Was Torn ?

THE DARK, UNFATHOMED CAVES OF OCEAN

WHATEVER the source of the water on the face of our planet, there can be no doubt that the seas were originally condensed from steam. The question remains: how are we to explain the present disposition of land and water ? How came there to be the great chasms and cauldrons that hold the great seas ? How has it come about that there is dry land at all ? It seems natural to assume that where there is sea there must be land; it seems natural to assume that the present proportions of land and water came about as a matter of course; but both assumptions are quite wrong. There might very well have been a sea covering the whole surface of the world—there is plenty of water for the purpose; and a very little rearrangement of the surface markings of the earth would vastly alter the distribution of its land and water.

The mean height of the land is 2250 feet; the mean depth of the sea is 13,860 feet, and the surface area of the sea is more than two and a half times the surface area of the land—about 144,000,000 square miles of sea, to 55,000,000 square miles of land. This means that the total bulk of sea-water is considerably more than thirteen times the bulk of all the land above sea-level. Whence again it follows that if the earth were a true oblate sphere of uniform density, its whole surface would be covered with water two miles deep.

Even a comparatively small rise or fall of the sea-level would have startling geographical consequences. A drop of 600 feet in the level of the sea would unite Britain and France, and would very quickly bring about the conscription Lord Roberts desires. It would also unite Asia and America by the Behring Straits, and attach Ceylon to India, and Papua and Tasmania to Australia, and would probably render it possible to travel dryshod from Sydney to Pekin and from Pekin to Klondkye. Altogether it would lay bare 10,000,000 new square miles of dry land. On the other hand, a rise in sea-level of 2000 feet would submerge the greater part of the dry land. It is just the depth and size of the great ocean beds that has chiefly decided the shape and size of the continents. From them have come the denuding waters, and carried to them the ruins of the lands wherein they streamed and delved.

Now, what delved or indented the ocean beds ? We have seen that the crust of the earth has been rising and falling in its continental areas in rather an amazing way; we have seen that æons ago, ere "Asia from her bathing rose," a sea flowed where now the snowy peaks of the Himalayas woo the evening star; but we have also seen that it is probable that the abyssal depths of the great seas have endured for countless ages. What made the bed of the Pacific, and what made the bed of the Atlantic Ocean ? By what natural agency were they made, and why are they so permanent and their shores so changing ?

To these great questions there are many answers, and yet no answer that has met with unqualified acceptance. We have already mentioned *en passant* the most interesting theory of all—the theory that the Pacific Ocean bed was a scar left in the earth's side when the moon was wrenched from her side.

This is certainly an interesting theory, a plausible theory, and a theory that appeals intensely to the imagination, but it is not proven; and even if one or two holes were made in this way in the crust of the earth, it is quite likely that they did not persist. At this time the earth was in a soft, plastic condition; and very probably under the influence of gravitation and

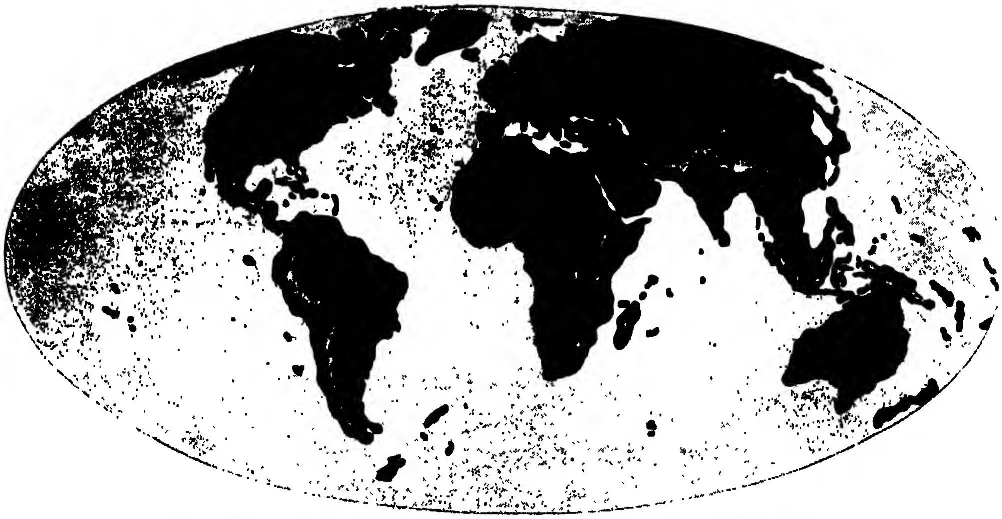
rotation the hole or holes would fill up, and the whirling mass would again acquire the pear shape it probably had at the time of its disruption. In this event, as we have previously said, the original sea would condense round the neck of the pear. Through the sea the point of the pear would project as a large island, while the broad end of the pear would form a great, continuous continent.

The original sea is still represented by the Pacific Ocean, but the original great continent is now broken up by the Atlantic and Mediterranean Seas, which were subsidences in the primitive crust. We have already described the changes in the contours of seas and continents which took place during the geological eras, but we may now briefly recapitulate the distribution of land and water in the Mesozoic Period.

At that period North America, Greenland, Iceland, and Northern Europe formed a continuous continent, connected by a narrow neck of land with the older continent of Gondwana, which included Africa, South America, Arabia, Southern India, and Australia. Most of Southern Europe was then covered by the ancient Tethys Sea, which not only divided Northern Europe from Africa, but also sent an arm north, dividing Europe from Asia, and an arm west over the position of the present Himalayas, separating the Indian and Malay Peninsulas (then incorporated in Gondwana) from the rest of Asia. North-Eastern Asia, thus cut off from India, Europe, and Africa, formed a huge island-continent known as Angara. The Atlanti at that time was represented by a immense inland lake (Lake Laramie which communicated with the Pacific by narrow strait where the isthmus of Sue now is.

That was the land and sea distributio in Mesozoic times, and a glance at the ma will show that great changes have take place since then. Australia is now separate from Africa by the Northern Pacific. Afric is separated from South America by th Southern Atlantic. Between Europe an America now stretches the stormy North Atlantic. While from the ancient Tethy Sea has arisen Asia Minor and the Himalaya mountains.

Leaving this interesting question of th *origin* of the great seas and sea-beds, let us now look at the great seas as they now are.



THE LAND THAT WOULD BE LEFT IF THE SEA SANK 600 FEET

The greatest sea is, of course, the Pacific Ocean, which has an area of 55,000,000 square miles—an area, therefore, equal to all the dry land of the globe. It contains many islands, but there are parts of it 2500 miles from the nearest continent. It is a deeper sea than the Atlantic; the greater portion of it is more than 14,000 feet deep, and there are parts much deeper. Off the coast of Peru there is a narrow trench over 28,000 feet deep. Off the east coast of Japan there is an area larger than New Zealand, known as the Tuscarora Deep, over 28,000 feet deep, and in one place near the Kurile Islands a depth of 27,930 feet has been recorded. South of the Friendly Island the deepest depth yet sounded has

been discovered. Here the lead shows a hole 31,000 feet deep. On the other hand, the Behring Straits are only 300 feet deep, and the sea between Asia and the Philippines and between the Philippines and the Australasian islands is rarely more than 300 feet deep.

The Atlantic Ocean, with its arms the Arctic Ocean and Mediterranean Sea, has an area of 33,000,000 square miles. It is essentially the ocean of rivers, for into it flow almost all the big rivers of the world—the Amazon, the Mississippi, the Orinoco, the La Plata, the Uruguay, the Parama, the Congo, the Niger, the Nile, the St. Lawrence, the Danube, the Rhine, the Rhone, etc. Though not so deep as the Pacific, it is, as a whole, deep, and in many places exceeds a depth of 18,000 feet. It by the Straits of Gibraltar. Comparatively speaking, it is shallow sea. Were it lowered even 600 feet it would cause great international and geographical consequences, for the Dardanelles and the Bosphorus wou'd become dry land, the Adriatic Sea would be almost entirely abolished, Majorca would join Minorca; Sardinia, Corsica; and Malta, Sicily. Were it lowered 1200 feet the Straits of Gibraltar would become an isthmus; and were it lowered 1460 feet it would be divided into eastern and western land-locked seas by an arm of land stretching from Malta to Africa. The Mediterranean is deepest towards its eastern end, where it attains a depth of 13,800 feet.

Besides these great open seas there are various seas quite enclosed by land—for example, the Caspian Sea, the Sea of Aral,

THE LAND THAT WOULD BE LEFT IF THE SEA ROSE 2000 FEET

is divided into two troughs, an eastern and a western, by a submarine plateau known as the Dolphin Ridge, which runs north and south, and over this plateau the water is rarely more than 12,000 feet deep. From this plateau rise Iceland, the Faroes, the Shetland Isles, the Azores, Ascension, and Tristan d'Acunha. The deepest sounding in the Atlantic Ocean was obtained about seventy miles north of Porto Rico. There the sea is over 27,000 feet deep.

The Indian Ocean is about half the size of the Atlantic, and has an average depth of 15,000 feet. Its deepest part is between Java and North-Western Australia, where it reaches a depth of 18,000 feet.

The Mediterranean is properly an arm of the Atlantic, with which it communicates and the great African lakes. The Caspian Sea is 18,000 feet in depth, deep enough to submerge four Ben Nevises piled on each other, and it covers a space larger than the British Isles. Both the Caspian Sea and the Sea of Aral are remnants of the ancient Mediterranean Sea, otherwise known as the Tethys Sea.

Though the great African lakes are now so far from the sea, there seems no doubt that they are oceanic in origin, for they are still tenanted by marine animals. These inland seas have been produced, of course, by the rising of the land, and not by the sinking of the sea. The Caspian Sea and the Sea of Aral became land-locked in process of that tremendous upheaval of ocean bed which culminated in the Himalaya mountains.

When we compare the contour of the floor of the sea with the contour of the dry land we find resemblances and differences. On the whole, the floor of the sea is more undulating and has more gentle gradients than the land, but, on the other hand, its mountains, often appearing above its surface as islands, rise more abruptly. So gradual are the gradients of the ocean floor that so far as hills are concerned a motor-car could be driven all the way from Ireland to Newfoundland.

What Walking on the Bed of the Ocean Would be Like

Professor Bonney contrasts sea floor and dry land thus: "If a model were constructed to exhibit the contours of the land surface and of the ocean bed, and if a cast were taken of this in some flexible material, which was then turned so as to make another globe, it would be found that on the former model a series of ridges, comparatively narrow and steep, formed an interrupted network, in the wide interstices of which the surface shelved down into basins of variable depth; while on the other a series of gentle and undulating plateaus were parted by narrow furrows, the beds of which were broken by somewhat deeper pits, corresponding, of course, with the mountain peaks of our globe."

Professors Chamberlin and Salisbury remark that "If the water were drawn off the ocean's bed so that it could be seen as land is, the most impressive feature would be its monotony."

We have seen that if the Atlantic Ocean were evaporated down to a certain extent it would be divided by the Dolphin Ridge into an eastern and western basin; and we have seen that similarly, in the case of the Mediterranean, eastern and western basins would be separated. This is typical of the nature of the ocean bed: it consists of basin-like undulations or depressions, and, *pari passu*, with a diminution of water the sea would be divided and subdivided into lesser seas in lesser-sized basins.

How the Floor of the Ocean is Creased and Lined

Here and there in the ocean bed occur deep channels, sometimes over a thousand feet deeper than the adjacent ocean floor. These are known as "swatches," and are supposed to represent ancient river-valleys that have been submerged by the sea.

Such, then, is the general depth and contour of the present-day ocean beds; and it is pretty certain that while the marginal boundaries of the basins have known many ups and downs within geological times, the bottoms of the deep central seas have remained down for countless ages.

Let us now look at the geological characters of the floor of the ocean—"the great, grey, level plains of ooze where the shell-burred cables creep."

Up till the middle of last century nothing was known of the nature of the deposits on the ocean floor, but the necessity of surveying the floor of the ocean with a view to laying cables stimulated research; and numerous expeditions, such as the expedition of H.M.S. "Challenger," in 1872-76, have given us a wealth of information with regard to the crust of the earth under the sea.

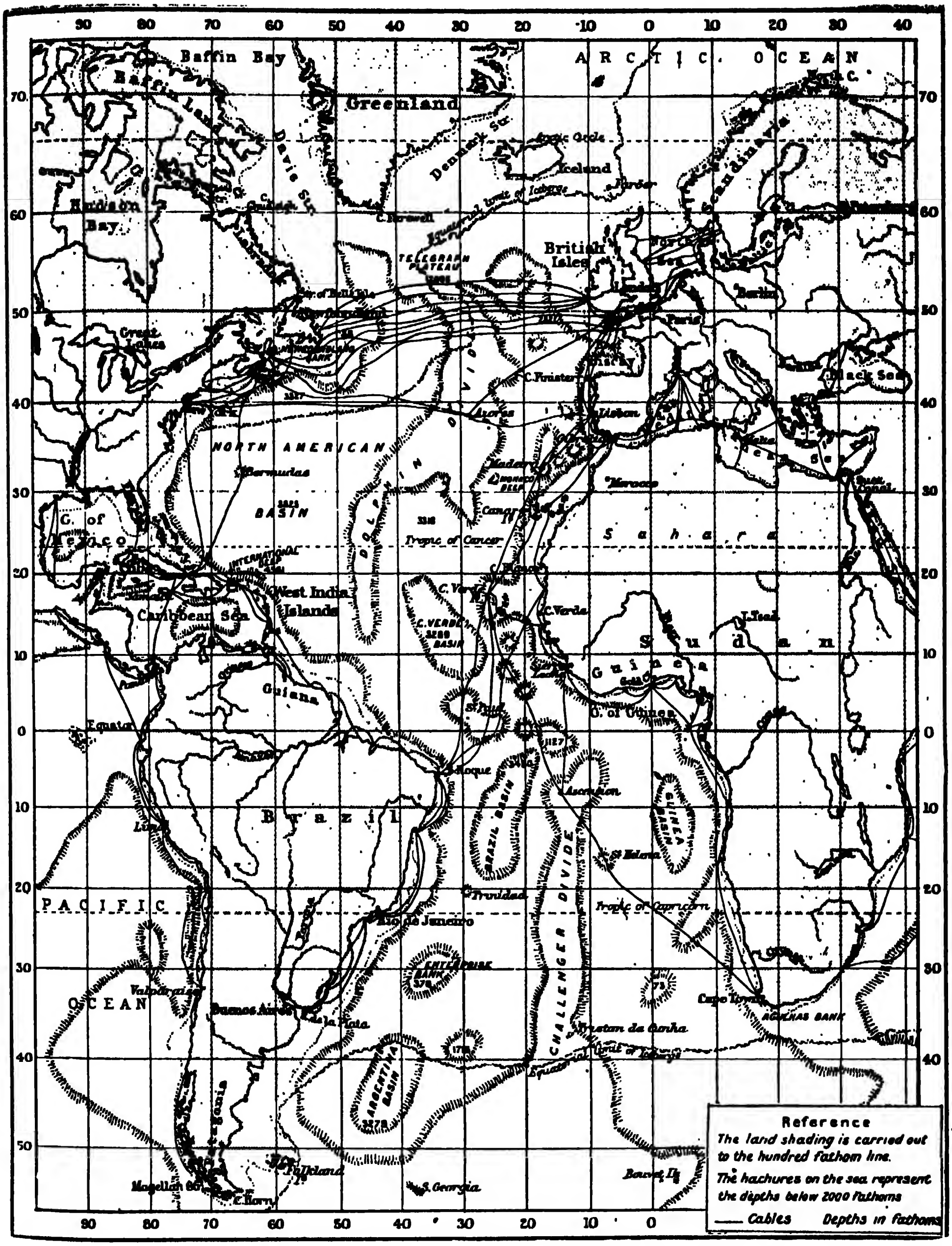
It is possible to procure samples of mud and ooze from the sea floor by means of a sounding lead slightly hollowed out at its lower end, and greased with tallow. When this lead strikes sea bottom a little mud adheres to it, and can be hauled up for examination, but scientific expeditions use more elaborate instruments for the purpose.

The scientists of the "Challenger" expedition, which did so much to increase our knowledge of the ocean beds, divided marine deposits as follows:

MARINE DEPOSITS

1. Deep-Sea Deposits (beyond 100 fathoms)	Red Clay Radiolarian Ooze Diatom Ooze Globigerina Ooze Pteropod Ooze	I. Pelagic Deposits formed in deep water remote from land
	Blue Mud Red Mud Green Mud Volcanic Mud Coral Mud	II. Terrigenous Deposits formed in deep and shallow water close to land masses
2. Shallow-Water Deposits (in less than 100 fathoms), sands, gravels, muds, etc.		
3. Littoral Deposits (beyond high and low water marks), sands, gravels, muds, etc.		

(*a*) Littoral Zone. The zone of deposits lying between high and low water mark has the well-known characters of the ordinary beach. It consists chiefly of sand, pebbles, and boulders derived from the land by the action of the tides, and of the rivers flowing into the sea. As a rule, the coarser material is flung highest up on the beach, and towards low-water mark the detritus grows progressively finer. The more sheltered the shore, too, the finer will the material of the beach be. Occasionally organic calcareous matter and fragments of shells are cemented together into rocks; and in some cases, especially on the shores of Arctic seas, there are huge accumulations of driftwood.



THE ATLANTIC OCEAN, SHOWING THE RELATIVE DEPTHS

The coasts of the world are about one hundred and twenty-five thousand miles in length, and the whole tidal area amounts to many thousands of square miles.

(*b*) Shallow-Water Zone. The sediment deposited in water less than a hundred fathoms deep is of much the same nature as the sediment of beaches. On the whole, it is finer, but it varies between mud, sand, and gravel.

(*c*) Deep-Sea Zone. The deep sea zone, as is seen in the table we have given, is partly formed from land débris or muds, and partly of the so-called oozes.

We shall first describe the muds. The distance from land to which land mud can be carried varies considerably. As a rule it is all deposited within two hundred, or, at the outside, two hundred and fifty miles from land. But pumice-stone, which is

light and porous, may drift a long way before it sinks, and large, rapid muddy rivers flowing into the sea can carry mud for a great distance. Congo mud, for instance, has been found 600 miles, and the mud of the Indus and Ganges 1000 miles, from the shores that produced it. Further, of course, volcanic dust may be carried by wind round and round the world before it sinks as mud to the bottom of the sea, and storms may carry ordinary dust for almost incredible distances. A certain quantity of mud and stones may also be carried by icebergs, and deposited a long way from the land of their origin.

The Muds That Coat the Untrodden Bottoms of the Ocean Bed

Almost all mud thus composed of detritus of the land contains little particles of minerals, such as quartz, mica, hornblende; and occasionally there are larger or smaller quantities of terrestrial vegetation, such as leaves, fruits, twigs, seeds. All earth-derived muds become dust when dried.

Now let us look at some of the specially named terrigenous muds.

1. Blue Mud. Blue mud is formed by powdered crystalline rocks mixed with decomposing organic matter and sulphide of iron. When iron is present in the form of ferric oxide, the mud often assumes a brown or red hue; and the surface layer of blue mud is often red or brown for this reason. Blue mud is often mud carried into the sea by rivers, and hence often contains terrestrial vegetable and animal matter. Usually, too, in such mud there is a certain amount of carbonate of lime, derived from shell-fish in the water.

2. Red Mud. Red mud, as we have already said, is simply blue mud containing considerable quantities of ferric oxide.

3. Green Mud. Green mud is produced when only a small amount of mud is carried into the sea. Such a small amount of mud gets more than its share of tumbling about, and is exposed for a long time to the action of sea-water. Chemical changes accordingly occur which give it a green colour.

4. Coral muds and volcanic muds require no special mention; they are produced from the débris of coral and volcanic rock respectively.

The Oozes that Drop Down From the Upper, Shell-Laden Waters

We now come to the very interesting subject of the oozes. The oozes are not formed from land materials washed into the sea, but mainly from the calcareous and silicious skeletons of deep-sea organisms. These organisms, often microscopic, have the power of collecting lime and silica from the sea-water and of building shells therewith; and when the organisms die the shells fall down and accumulate on the ocean floor.

1. The Pteropod Ooze. The pteropod ooze consists chiefly of the shells of pteropods and gastropods—species of shell-fish which live at the surface of the sea in great shoals. It is found chiefly on the submarine ridges of tropical seas, and never occurs at greater depths than 1000 fathoms. The reason of this limitation in depth seems to be that the delicate shells are gradually dissolved as they fall through the sea-water; and by the time they reach greater depths than 1000 fathoms have dissolved altogether. Pteropod ooze is known to occur over an area of 257,000 square miles.

2. The Globigerina Ooze. The globigerina ooze consists mainly of the shells of certain minute shelled organisms known as *Globigerina bulloides*, which belong to the order Foraminifera. When these shells are examined under the microscope, they are seen to be composed of several inter-communicating chambers pierced with numerous apertures. When the organism is alive, its soft, jelly-like body occupies the chambers, and thread-like arms pass through the apertures and wave about in the water. After death, as the dead organism falls through the water, the body is dissolved and only the tiny shell reaches the sea floor.

The Shells That in the Ages Lay Down at the Bottom of the Sea, Future Hills of Chalk

Where the sea is deeper than 2000 fathoms, not only the body of the organism but also the shell is dissolved, and so globigerina ooze is seldom found in seas deeper than 2000 fathoms.

In appearance the globigerina ooze is a fine, creamy, pinkish or greyish mud. When dried, it becomes a chalk-like substance which may be used like chalk to write with. It is really essentially the same as chalk, consisting mainly of carbonate of lime, and effervescing when treated with acid. It is estimated that no less than 47,752,500 square miles are covered with this calcareous ooze. In the Atlantic alone it covers an area measuring at least 1300 miles from east to west, and several hundred miles from north to south. Yet it requires about 10,000 globigerina shells to cover the space of one square inch.

All over the ocean, except in enclosed seas and cold Arctic currents, this ooze is forming. All over the ocean floats a colossal cloud of

these delicate, shell-creatures, and downwards from the cloud streams a rain of the dead. "A never-ceasing rain of dead shells, light as the dust which drops unfelt from the atmosphere, patters down silently and incessantly on the ocean floor." Slowly and gradually does the ooze accumulate. On the Atlantic cables it has been found to collect only at the rate of ten inches in a century. Yet the rain goes on, not for centuries, but for æons, and in time inches grow feet, and feet yards. Even if the Atlantic and Pacific Oceans have been raining globigerine for only four hundred thousand years, each would have collected enough ooze to bury Snowdon.

How deep was the calcareous ooze in the bottom of the ancient seas testify the chalk cliff and chalk mountains—the Needles, Mount Sinai, Mount Lebanon—for of ancient calcareous ooze were they built. As we have already mentioned, the chalk cliffs of England were formed of the chalky ooze of an ancient sea that millions of years ago flowed over the present site of the British Isles, and this ooze must have been about 1500 feet thick. In other places the ooze may perhaps have reached a depth of no less than five thousand feet.

The Geology of the Sea Bottom the Geography of the Future

However deep the present-day deposits of globigerina ooze may be, they are pregnant with great possibilities, for they are the stuff whereof future islands and continents and mountains may be made. One day there may be a resurrection of all these dead globigerines, and the resurrection may be a mountain range. Down in the depths of the sea Nature may be working out her plans.

Mixed with globigerina ooze are multitudes of microscopic little calcareous discs called "coccoliths," which are sometimes massed together into spheroidal bodies which are called "coccospheres." These are usually supposed to be algæ or the spore-cases of algæ. Other calcareous bodies known as "rhabdoliths" and "rhabdospheres" also occur.

3. Diatom Ooze is an ooze formed principally of the siliceous skeletons of the microscopic little vegetables known as diatoms. Siliceous shells are not dissolved as they pass through water, and hence they occur at all depths. Diatom ooze occurs chiefly in the Antarctic, where "at an average depth of about 2000 fathoms there is a wide band of soft, white ooze covering the sea-bottom between the parallel of 40° S., and extending to the Antarctic circle and completely surrounding the southern hemisphere. This band has an area of over ten millions of square miles."

4. Radiolarian Ooze.—Diatom ooze, as we have said, consists mainly of the siliceous shells of minute *plants*. Radiolarian ooze, on the other hand, consists chiefly of the siliceous shells of minute animals. These minute creatures have a very wide distribution, and in their siliceous remains accumulate as a deep-sea deposit in various parts of the sea.

The Teeth That are Undissolved When All Other Animal Substances Have Disappeared

5. Red Clay. Though red clay may be considered among the oozes, it differs from the oozes in the important particular that it is mainly inorganic, and contains hardly any organic remains. It is found only at great depths, and at a great distance from land, but it is the most widely distributed of all the sea deposits, covering an area of over 50,000,000 square miles, including more than half the area of the Pacific Ocean.

Mineralogically, red clay consists mainly of volcanic material in a pulverised condition, together with meteoric dust and dust from deserts. Its red or brown colour is caused by the formation of ferric oxide and manganese peroxide in the process of the decomposition of the volcanic material. Manganese nodules about the size and shape of large potatoes lie pretty plentifully upon its surface. In the centre of these nodules, acting as a nucleus, is often found some hard substance, such as a piece of pumice-stone or a shark's tooth. Specially characteristic of red clay are the teeth of sharks and the ear-bones of whales. No other bones are found: all other bones are quickly dissolved under the conditions existing in these abysmal depths, and these alone survive because of their excessive hardness. The sharks' teeth belong to species that must have been extinct for long ages.

The Old, Old Story of the World's Past Hidden in the Slowly Laid Floor of the Sea

Very strange it is to think that the bottoms of the deepest seas are plastered over with the dust of volcanoes and shooting-stars, and sprinkled with the teeth of extinct sharks. Part of the volcanic débris may have come from submarine volcanoes, but the greater part is probably carried by the wind from volcanoes on the dry land. This red clay sediment must be formed exceedingly slowly, otherwise the teeth of the extinct species of sharks and ear-bones of extinct species of whales must have been buried out of reach long ago.

GERM-CELLS THE BASES OF HEREDITY

THE FRUITING AREA OF BLADDER-WRACK, IN WHICH MALE GERM-CELLS ARE DEVELOPED

CONCEPTACLE OF BLADDER-WRACK, IN WHICH FEMALE GERM-CELLS ARE DEVELOPED

In the upper picture the spermatozoids can be seen in their receptacle, and in the lower are seen the large, dark-coloured egg-cell which are fertilised by the spermatozoids. These highly magnified photographs are by Mr. J. J. Ward.

STUDIES IN HEREDITY

How Darwin and Galton Made a New Scientific Orthodoxy which Has Already Been Superseded

THE FAILURE OF RESEARCH BY ARITHMETIC

If we recall our study of reproduction, we shall realise that heredity offers no problem in the simplest possible instances. The bacillus or the amœba divides into two, and as each is half the parent, its resemblance to the parent is in the nature of the case. As regards the amœba, which has a nucleus, we saw that the contents of the nucleus are scrupulously subdivided between the "offspring," to use a word which is evidently not yet applicable to the process of reproduction in such humble forms of life. In the case of the yeast plant we can speak of "offspring," for the young cell does spring off, so to say, from the parent; but it is palpably part of the parent, and again the resemblance between the generations offers no problem to the student of heredity. Further, in such cases as these, which are drawn both from the animal and from the vegetable kingdoms of the living world, the new individuals are born adult. They have no youth, no immaturity, no period of development. So much the less is there any problem to study. We do not have to compare mature parents with immature offspring; we do not have to ask how the development of offspring, from immaturity up to a condition in which they resemble their parents, is made dependent upon the composition of "germ-cells" in which no trace of the future organs and limbs and features can be observed by the most powerful microscope.

Nevertheless, let us duly note these cases, and their simplicity; for the great initial discovery, upon which modern genetics is based, was the tracing of the hereditary process, in even the very highest forms of life, to just this same simple, continuous cell division as the amœba illustrates. That, in a word, is what the theory of the germ-plasm and the "continuity of the germ-plasm" means; and when we talk of germ-cells and study their divisions, though they be the germ-cells of an oak or of human beings, we are studying a series of processes which are, in essentials, absolutely identical with the division of the amœba, though hidden from our eyes by the extraordinary development of the individual body from and around these germ-cells. And thus, if the resemblance between daughter amœbæ and the parent amœba is really no problem—for they are the mother, subdivided—so also the resemblance between successive generations of other species is seen to be inevitable, for the body of the parent is sprung from a "continuous germ-plasm," of which a further portion, reserved for the purpose years later, gives rise to the body of the offspring. Naturally, then, parent and offspring resemble each other in so many particulars, the bodies of both having really been developed from almost the same material.

If this be a sound conception of the process of heredity, if the sequence of the generations be not from parental body to germ of offspring, but from germ to germ, with the parental body as a bridge or a protective host, performing a temporary service for the "immortal germ-plasm," then we may begin to doubt whether the accidental happenings to that parental body can affect the germ-race within it, or the features of future bodies which may be developed therefrom. Thus, if the parental body "acquires" the character of losing an arm, we need not expect that this accident will affect the germ-plasm, and the number of arms of future offspring, any more than if the parent had lost not his arm but merely the sleeve of his coat. In either case the loss is irrelevant to the history of the germ-plasm which the arms of the individual body (and the sleeves covering them, for the matter of that) exist

primarily in order to protect. Very different would the case be if Darwin's theory of pangenesis were true, and the germ-cells were made by contributions representative of every part of the individual parental body; but that, as we have seen, is not the case.

This assertion, that the modifications of the parental body, which is merely the host or trustee of the germ-plasm, do not affect it, and are therefore not transmissible to offspring, was first laid down by the late Sir Francis Galton. This theory is generally credited to Weismann, and undoubtedly Weismann has done the greater part of the work associated with it, as we shall see, but the first denial of the commonly accepted view—which played a large part, we remember, in the evolutionary system of Lamarck—was made by Galton. Here is his own statement, made at a later date, of the view in question: "As a general rule, with scarcely any exception that cannot be ascribed to other influences, such as bad nutrition or transmitted microbes, the injuries or habits of the parents are found to have no effect on the natural form or faculties of the child."

The Position of the Study of Heredity when Galton Took up the Subject

The reader should note the words "bad nutrition or transmitted microbes," for they indicate two great realms of causation that have been generally forgotten by students and advocates of the Galton-Weismann theory. But we shall see this more clearly when we come to study Weismann's contributions to the subject.

Those contributions depend upon a particular line of research, the microscopic study of germ-cells, which made a new chapter in the study of heredity, and is adding to that chapter to-day. But first we must deal with Galton's work, his characteristic method, and the results to which it has led. He founded a definite school, which has attained great prominence in London, though not elsewhere, and the members of which are now contributing copiously to the literature of the subject.

When Galton came to the study of heredity, half a century ago, he found it a chaos. A sharp distinction was made between heredity in animals and heredity in man; most authors would admit the fact of heredity in animals, but denied it in man—a state of mind remarkably similar to that of the present representatives of Galton's method, who admit the Mendelian law of inheritance in animals, but not in man! But of that more anon. The time was ripe for a fresh start. The "Origin of Species" had just been published by Galton's cousin, and the importance of the study of heredity had risen accordingly, and it had become of even sensational interest, not least as regards man, whom the Darwinian theory classed definitely with the lower animals. As Galton says, "The subject of human heredity had never been squarely faced, and opinions were lax and contradictory. It seems hardly credible now that even the word heredity was then considered fanciful and unusual. I was chaffed by a cultured friend for adopting it from the French."

The Incalculable Service of Galton's Study in Calling Attention to the Question

Galton had himself inherited a strong statistical bent. He liked to reduce everything to numbers, and then study and compare them. The present writer has heard him describe his method of measuring attentiveness in an audience, by counting the average number of fidgets per minute in random groups of five persons, using his pulse as a watch. His study of heredity was accordingly statistical in conception and in detail from first to last, and the conclusions which he reached are statistical laws, capable of mathematical expression. His services to the study of heredity, by his interest in it and the discussion his work aroused, are incalculable, but we must pay no reverence to any statement or theory which proves to be erroneous, and unfortunately time has played sad pranks with the greater part of Galton's work, chiefly owing to the work of his contemporary Mendel, who was born in the same year, 1822, and to whom he has paid generous tribute.

Galton's Statistical Examination of Variations to Illustrate Darwin's Ideas

We have already seen that it is all-important, in our study of heredity, to distinguish between true variations, which have their origin in the germ, and the mere results of the interaction between the individual and the environment. Those results may alter the individual in various ways, including the chance of modified nutrition, and of infection with microbes, so that the individual's relation to his offspring is different from what it would otherwise have been. But while these particular differences wrought in the individual are important from the point of view of his offspring, neither they nor any other "acquired characters" or "functional modifications" have any bearing upon his relation to his ancestors. Therefore, in our

study of the measure of likeness and unlikeness between any individual and his or its ancestors, we absolutely must exclude the influence of environment upon the individual. That may be difficult or impossible, but if it is not done we cannot decide as to what heredity is doing in the case in question.

Now Galton was Darwin's cousin, and his interest in heredity was chiefly aroused by the book in which Darwin had declared the natural selection of small random variations between members of a species to be the efficient cause of organic evolution, and of the adaptation of living species each to its niche in the world. Hence the study, as exact as possible, of these alleged variations became immensely important, and the method of Galton was to attack the problem statistically. Let us have large numbers of individuals measured, in various respects, have the measurements compared, and then we shall be able to state a "law" of the distribution of variations. And thereafter we shall be able to see how natural selection of the favoured instances among these variations would effect the "origin of species." Such were the lines of reasoning, and a new edition of a well-known book on these lines has just been issued.

The Galtonian Mistake of Including Variations that were Not Transmissible

But if the mere results of external accident, as regards a thousand factors, are not transmitted by heredity, we shall make no useful contribution to anything unless we are quite certain that the random variations we study and measure are genuine germinal variations, inherent and therefore transmissible, instead of being superposed from without, and therefore shed with the shedding of the individual as the race goes on. And that is where all this enormous mass of work has broken down in recent years. The workers have done everything else, but they have left undone what was really the first task of all, which was to prove that the differences they observed were inheritable. We call them "variations," which we have agreed to define as germinal, not "acquired," but if we find that they are not germinal we shall want a new name for them. At first, when their real character was suspected, biologists called them "fluctuating variations," and now they are very generally spoken of simply as "fluctuations."

This is a most instructive chapter in the history of science, for it teaches the old lesson—that we must keep close to the facts unless we are content to go wrong. Names and numbers will not do, if they do not agree with things. The pioneers in this case are not to be blamed, but their smaller followers, as in a thousand other instances. Darwin was a first-hand observer, and made many experiments. If this had been a task for one man, or for ten ordinary men, he would have done it. As it was, Darwin could only collect materials for the future study of variation. It is in the nature of this kind of work to require time, as astronomy does—you cannot observe characteristics of great grandchildren, and compare them with their ancestors, until life has reached them. Galton, also, made many first-hand observations, some of the highest value, such as those already quoted, which disposed of Darwin's theory of "pangenesis."

How Galton's Followers Continued to Stereotype His Errors of Classification

But the followers of these great men went on other lines. They counted and calculated and assumed. To them a variation was a variation, and its transmissibility could be taken for granted. Their great concern was to discover how these variations were distributed, and thence to reckon what effect various degrees of selection would have upon the race; not troubling to remember that the selection of not inheritable characteristics would have *no* influence on the race. Their calculations resulted in a very definite conclusion, which entirely agreed with the assumption of Darwin, that variations occur in all directions. These measurers of life, or "biometricians," as they are now called, showed that offspring vary in all directions from the type of the parents.

"Variation"—only we must beware of the word—was essentially an affair of the law of chance. Curves could be plotted, showing the distribution of variation among the individuals of a given generation, and it could be shown that this obeyed, as a whole, a law very familiar to mathematicians.

The Futility of Laws of Average that Prove Nothing at All

If we examine all the shots upon a target after very many have been fired, we find that they have a "probable error," that can be measured. Most will be near the bull's-eye, and there will be a gradual thinning as we leave it, until we encounter only a stray shot here and there; and we can readily predict, in a simple formula, the proportion of the total number of shots that will probably show any particular measure of error from the path to the bull's-eye.

Now it is a fact, statistically proved by these students, that if we examine a very large number of peas or people, leaves, hairs, or almost what you will, this law is illustrated by them. There is a sort of average or mean for them, and the further we depart from that, on either side, the fewer will be the number of individuals represented. It is just what a soldier said of a regiment—in every hundred men you will find ten who will storm the gates of hell, ten who would run away if they got the chance, and eighty who will follow if they get a lead. Measure the lengths of the hairs on a leaf, or the length of the legs of ten thousand men, and we get just a similar result.

Laboratories of Life Into Which No Living Creature was Taken for Observation

All this, when studied in detail, becomes very interesting, and is found to be perfectly true. It is exactly what is required for the theory of the origin of species by the natural selection of minute variations which favour survival. Distinguished mathematicians have constructed elaborate and consistent theories of the details of organic evolution, supposed to occur in this fashion, and Galton himself was unfortunately misled, making no experiments in the later decades of his life, and devoting large sums of money to the establishment of "laboratories" for the study of life into which no living creature is ever taken for observation.

The rediscovery of the work done by Mendel many years before had led to many indirect as well as direct consequences. One was a sudden revival of interest in actual breeding experiments, which had been astonishingly neglected while men argued and wrangled and reckoned over theories contained in the "Origin of Species." Only actual breeding experiments could really meet the needs of biology. Darwin did his best, but for the most part he was compelled to rely upon the statements of breeders of cattle, gardeners, fanciers, and others, whose motive was not scientific, and whose training was no more so. Of course, this could not do.

The Statistics of Variation Proved by Experiment to be Beside the Mark

At whatever expense, at whatever cost of time and labour, biologists were plainly required to make breeding experiments, to which there will never be any end, and thus "to put the question to Nature," as Bacon said, definitely and rigorously, so that Nature might return definite and rigorous answers. The last decade has witnessed the practice of such experiments, by men of science with purely scientific ends, on a scale which is certainly not one-millionth of what we need, yet which far exceeds anything of the kind ever attempted by man. Since then "everything is different."

The most remarkable and important discovery of all, negative, indeed, yet more important even than the positive results attained long before by Mendel, is that these "fluctuating variations" or "fluctuations," in all directions, with a regular distribution, from the mean or type of the species, ***are not inherited.*** They are not germinal, but nutritive—dependent upon the relations between the individual body and the chances of the environment, and thus occurring, on the average, according to the mathematical laws of chance. Not being germinal, these variations, so called, are not inheritable, for inheritance, as we have seen, is really from germs to germs, under cover, so to say, of the individual bodies which contain them. The "variations" so minutely studied were only differences between those bodies, and are therefore seen to have nothing to do with the process of heredity, and therefore ***nothing to do with organic evolution.***

Dissolution of the Orthodox Theories of Heredity Inherited from Darwin through Galton

The writer has failed inexcusably if he has not made plain to the reader the fundamental and overwhelming importance of this conclusion. At one touch of first-hand knowledge, rightly obtained for the special purpose in question, the whole structure of the orthodox theory of evolution, built upon numbers and formulæ and curves on paper, is dissolved. The reading and intelligent public knows nothing of this hitherto, with very few exceptions. Professor Bateson's first course of lectures on "The Study of Genetics," delivered at the Royal Institution, must have given any amateur student of these subjects a series of surprises. Such amateurs, in this country, are largely interested in the subject from its bearings on religious belief. They have read the works of Haeckel and Grant Allen, Mr. Edward Clodd, and Mr. Joseph McCabe, as well as their volumes of Darwin and Huxley; and they have come to the inevitable conclusion that, as against Genesis, Darwinism must prevail. Genesis for them is orthodoxy, the conventional view in which they were brought up; and Darwinism is the heterodoxy, the daring novelty which the champions of new truth must accept. Let us remind ourselves that Darwinism is

only a particular theory to account for organic evolution, which is itself, beyond all question, true, and then let us picture the bewilderment of any ordinary well-informed reader of these subjects who heard Professor Bateson's frequent references to "the orthodox theory," "the conventional interpretation," "the views which we were brought up to believe." These references, inevitable and natural, considering the nature of his subject, and before long quite unremarkable to the ears of those who listened intelligently, were not to Genesis, but Darwinism.

Not even the youngest of us were all brought up to believe in Darwinism as the conventional and respectable view of orthodox people; but if we were, it is time for us to make a fresh start. The assiduous and devoted mathematical study of variation, initiated by Galton, and hailed by certain of his successors as conclusive in its proof of the efficiency of natural selection of minute variations in the formation of new species, avails nothing at all in presence of the demonstration by Nature, when the question is put to her, that these variations are not inherited.

How the Beginning of the Study of the Problem of Species was mistaken for Its Completion

It is the end of a strange chapter in the history of science, but apparently many years will pass before the general knowledge of the community is aware how far biology has gone, in our own century, beyond the furthest point reached even by Darwin.

Here are words written by Professor Bateson in 1909, the Jubilee year of Darwin's masterpiece:

"The *Origin* was published in 1859. During the following decade, while the new views were on trial, the experimental breeders continued their work, but before 1870 the field was practically abandoned. In all that concerns the problem of species, the next thirty years are marked by the apathy characteristic of an age of faith. Evolution became the exercising ground of essayists. The number, indeed, of naturalists increased tenfold, but their activities were directed elsewhere. Darwin's achievement so far exceeded anything that was thought possible before, that what should have been hailed as a long-expected beginning was taken for the completed work. I well remember receiving from one of the most earnest of my seniors the friendly warning that it was waste of time to study variation, for Darwin had swept the field."

And Darwin had never even heard of Mendel! One gasps at the blindness of that advice; and yet one may be saying the same thing to a junior thirty years hence, with Bateson's name instead of Darwin's!

So much for the most important fact which research has brought to light since the mathematical study of variation was initiated. Fluctuations are not inherited; and all the criticism of the theory of natural selection, which we have put forward in previous chapters, based partly on the writings of Bergson and partly on other grounds, may be regarded as superfluous from the practical standpoint, for the all-sufficient reason that, with the disproof of the inheritance of fluctuations, the whole theory of organic evolution by means of natural selection falls to the ground.

The Absence of the Absent Accounted for, but Not the Presence of the Present

The theory will account for the absence of the absent, because they were not able to survive in the struggle for existence, and that is a most important contribution to our knowledge, but it tells us nothing as to the presence of the present. We may refrain from observing that the origin of variations has to be accounted for, we may recognise the fact of adaptation in fullest degree, we may grant that variations around the type of any species will some of them tend to favour survival, and will therefore be selected for life and parenthood, but when, at this point, we find that those variations, having been selected, are not inherited, the bottom drops out of the chariot of our fancy, and when we pick ourselves up it is not for further adventures in that vehicle.

But if our history of this chapter in biology is to be at all complete, we cannot leave it without reference to two famous laws, or generalisations, which were framed by Galton, and which are still very frequently referred to in semi-popular writings, and by the biometricians, though they no longer interest biologists very much.

The Arithmetical Basis of Galton's Law of Ancestral Inheritance

The first "Galton's law" is also often called the "law of ancestral inheritance." Its author made a statistical study of a very large number of data as to health, eye-colour, stature, etc., in several generations of some hundred and fifty distinct families. Then he made a similar statistical analysis of the colours of a large pedigree stock of Basset hounds. And he found that, both for the human beings and for the dogs, the following law could be affirmed: "The

two parents between them contribute on the average one half of each inherited faculty (or character), each of them contributing one-quarter of it. The four grandparents contribute between them one-quarter, or each of them one-sixteenth, and so on, the sum of the series, $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16}$, etc., being equal to one, as it should be. It is a mathematical property of this infinite series that each term is equal to the sum of all those that follow."

The Failure of the Law when Tested by the Study of Actual Cases

In his book, "Variation in Animals and Plants," published in 1903, Dr. H. M. Vernon, a well-known authority, expressed the opinion that Galton's law "renders the whole theory of heredity simple, straightforward, and luminous." How times have changed! Dr. Vernon did not then know the fatal objection which experiment was to bring against any theory of heredity that depended in any degree upon the study of characters that are *not inherited.* The first-hand study of the details of breeding, *with analysis of each individual case,* instead of statistical jumbling of all cases in one wild confusion—which looks orderly because it can be numbered precisely—led in half a dozen years to the verdict of Bateson that, "no one familiar with breeding, or even with the literature of breeding, could possibly accept that theory as a literal or adequate presentation of the facts." And this was the "law" which, a few years earlier, had been said to "render the whole theory of heredity simple, straightforward, and luminous!"

Little better is the fate which has overtaken the second of Galton's chief generalisations, the "law of regression to mediocrity." This is another statistical assertion, based essentially upon the putting together, which means the confusion, of large numbers of individual *data,* as opposed to the method of analysis of each *datum* separately.

The Lengthy Literature of Galton's Law of Regression to Mediocrity

Ten years ago, and less, practically everyone accepted both of these laws of Galton, and based arguments upon them in relation both to natural selection and to the theory of eugenics. But the "law of ancestral inheritance" has had to be abandoned in face of the evidence, and later it has become clear that the law of "regression to mediocrity" must go also. This law asserts that there is a constant tendency for offspring of parents who have varied from the type, either on one side or the other, to return to it. This return is called regression, a very good name for it, and it constantly tends to keep the species along the line of the great majority of its representatives—that is to say, along the line of mediocrity. Thus the offspring of exceptionally tall plants, shall we say, will be taller than mediocrity, but not so tall as their parents; and the offspring of exceptionally short ones will be shorter than mediocrity, but not so short as their parents. Similarly, the children of genius will be clever, but nearer mediocrity than their parents; the children of criminals will be wayward, but less so than their parents, and so on.

This "law" could be written about, and has been written about, at any length. We can no longer accept it. The same radical confusion between the truly germinal and the results of environment pervades it throughout. It does not survive the test of experiment. Further—and this is the most unexpected argument—we begin to see that this law, which sounds so scientific and exact, is really quite mystical and unreal. We learn to look at it so from the very first day on which we start our study of germ-cells. We learn that the characteristics of the individual depend on the composition, contents, and structure of the germ-cells that make it.

The Failure of the Law of Regression when Tested by Experiments

According to the law of "regression towards mediocrity" one would have to examine the ancestors of any individual in order to learn its future. If the individual came of parents, say, very tall, whose tallness was the mediocrity of their stock, then the offspring would be as tall; but if the parental tallness were exceptional, then the offspring would "regress" and not be so tall as their parents. In so far as illustrations can be cited for such a theory, they depend upon exceptional nutritive or environmental conditions—*e.g.,* bad nurture stunted the parents, and the offspring are taller. This has nothing to do with heredity, though it looks like an illustration of "regression towards mediocrity." The hereditary or natural characteristics of the individual depend not on the features of the bodies of its parents and grandparents and so forth, as is assumed in the "laws" of Galton, but upon the facts of the actual germ-cells from which the individual is developed. In a word, we have put these

magnificent statistical generalisations under the microscope, and we find that there is nothing in them; the microscopic study of germ-cells has shown us their unreality, once and for all.

Here are the bold and unequivocal words used by Professor Bateson, in 1909, much criticised at the time, but now hardly noteworthy—so amazingly rapid has been the development of our knowledge and understanding since the students of heredity went back to the facts from their figures and curves. Professor Bateson is dealing with the state of things prior to the rediscovery of Mendel—"with the year 1900 a new era begins"—in the last year of the nineteenth century, and he says:

"Of the so-called investigations of heredity pursued by extensions of Galton's non-analytical method, and promoted by Professor Pearson and the English Biometrical School, it is now scarcely necessary to speak. That such work may ultimately contribute to the development of statistical theory cannot be denied, but as applied to the problems of heredity the effort has resulted only in the concealment of that order which it was ostensibly undertaken to reveal.

The Hopelessness of Methods which Dispense with Great Essentials

"A preliminary acquaintance with the natural history of heredity and variation was sufficient to throw doubt on the foundations of these elaborate researches. To those who hereafter may study this episode in the history of biological science it will appear inexplicable that work so unsound in construction should have been respectfully received by the scientific world. With the discovery of segregation—the peculiar behaviour of germ-cells, upon which Mendel's law is based, as we shall see—it became obvious that methods dispensing with individual analysis of the material are useless. The only alternatives open to the inventors of those methods were either to abandon their delusion or to deny the truth of Mendelian facts. In choosing the latter course they have certainly succeeded in delaying recognition of the value of Mendelism, but with the lapse of time the number of persons who have themselves witnessed the phenomena has increased so much that these denials have lost their dangerous character and may be regarded as merely formal."

Let us praise great men, and honour Galton for having admitted the fact of Mendelian segregation, in the autobiographical volume which he published in 1908, three years before his death. But meanwhile his followers have committed themselves irrevocably to methods which their master would now be the first to recognise as obsolete and inadequate; and if anything were needed to justify the very strong words which Professor Bateson wrote, in 1909, regarding the uselessness of methods which dispense with individual analysis of the material, that justification is to be found in the subsequent reports of the biometricians on the influence of parental alcoholism upon the offspring, when they omitted to ascertain, in a single case, whether the parental alcoholism had occurred before or after the conception and birth of the offspring, and on the alleged inheritance of tuberculosis, where they omitted to take into account the fact that tuberculosis is an infectious disease.

Going Back to Nature the Only Sound Method of Biological Study

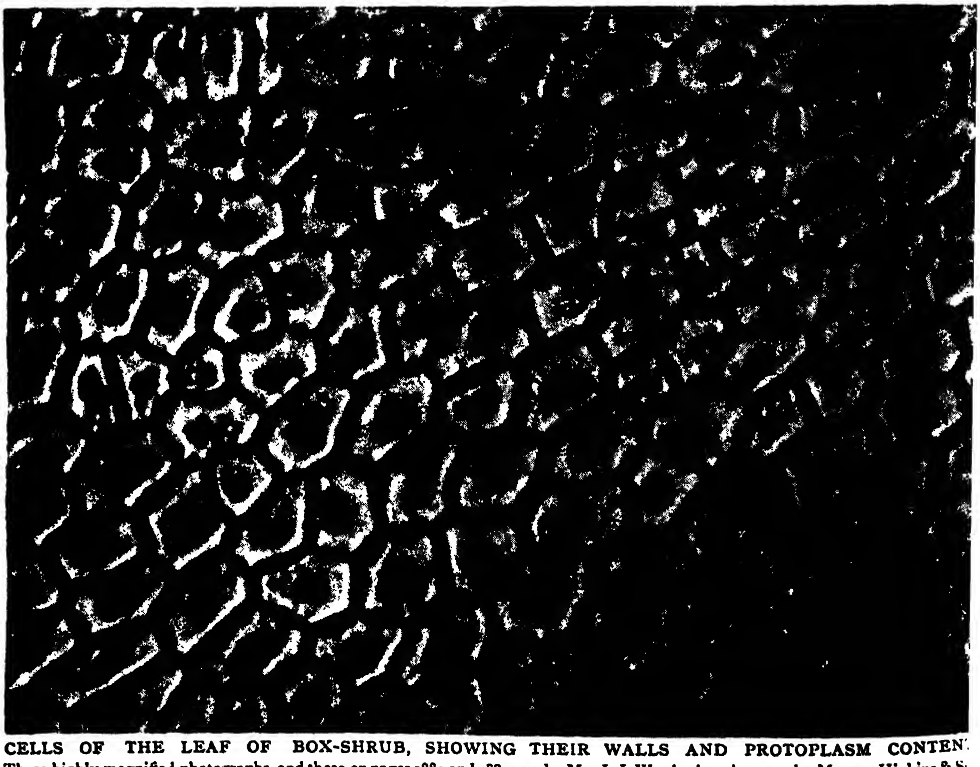
No; the study of living things cannot be conducted by the manipulation of figures and formulæ at a desk. In order to study them one must live with them and watch the details of their lives. We must go back to Nature. That is exactly what biology, all over the world, has done since the dawn of the present century, after very nearly a generation of words and numerals. The nineteenth century was not wholly without men who would not be drawn away from the only method by which natural science has ever taken a single sure step. Darwin, of course, was the greatest of them. He did not sweep the field, but at least he surveyed it.

How the Veteran Weismann Restored Living Contact with Living Things

Mendel was another, but by the accident of the remoteness of Brünn from London or Paris, or even Berlin, his work of 1865 dates, in the development of biology, from 1900, the year of its recognition. Weismann was another, a pioneer still alive, though the work of Mendel, nearly twenty years dead, is leaving Weismann's behind. But we should not be where we are without the veteran of Freiburg, rightly named August; and his study of germ-cells will restore us to that living contact with living things without which the science of life must ever languish and die. Nay, more; for Weismann has served science no less by interpretation than observation; and, like Darwin and Galton—though all three may now be largely superseded—he put forward clear and arguable ideas, which have stimulated thought and inquiry to new and vital efforts.

THE PROTOPLASM IN THE PLANT CELL

MARINE ALGA WITH CELL FILAMENTS, SHOWING GRANULAR PROTOPLASM WITHIN THE CELLS



CELLS OF THE LEAF OF BOX-SHRUB, SHOWING THEIR WALLS AND PROTOPLASM CONTENT

These highly magnified photographs, and those on pages 1882 and 1884, are by Mr. J. J. Ward; the others are by Messrs. Hinkins & S

THE BASIS OF PLANT LIFE

Protoplasm, the Stuff From Which All the Varieties of Plant Life Spring and are Fed

THE BED-ROCK OF THE STUDY OF ORIGINS

IN several sections of this work dealing with the phenomena of life, animal life, and plant life, references have been made to the wonderful substance which may be regarded as the basis of life, namely, protoplasm. Some of its properties and qualities have been discussed, but we have now to examine it rather more systematically. It is the living principle in all plant-life, and the study of protoplasm is more easily and successfully carried out in connection with plants than with animals; hence much attention has been paid to the study of protoplasm by botanists, who regard the science of botany as underlying the study of the whole science of life. That is why students who are entering upon any kind of biological training begin that training with the study of plants. What they learn in the study of botany is really the sum total of the infinite variety of possibilities that there are in the activities of protoplasm. We, therefore, realise that here we are on the bed-rock of things.

We may take a swift glance at the history of the main discoveries in plant knowledge, all of which, of course, have had attention drawn to them originally by men who were in search of knowledge which would help them to understand what life itself is. All these investigations of a biological kind are ultimately efforts to answer the question "What is life?" Perhaps the greatest stimulus to the search for this knowledge was given to mankind by the discovery of magnifying glasses, and subsequently of the microscope. It was thought that these, by revealing what was taking place in amongst the minute structures of living things, structures far too minute to come under the observation of the human eye unaided, would throw some light upon the nature of life itself.

One can readily appreciate the state of mind, therefore, of the Dutch philosopher Swammerdam, who, as the result of the marvels seen through his primitive lenses, almost went out of his mind. To such an extent was he alarmed that he actually destroyed the notes he had made of his observations, and came to regard such work as absolute sacrilege. Leeuwenhoek made a number of observations from 1632 onwards, none of which were accepted at the time, so extraordinary did they appear to those who had not used a magnifying glass. It was reserved for Robert Hooke, an Englishman, to substantiate the fact that very minute organisms, much smaller than had hitherto been imagined, could be shown under the magnifying glass. They were shown in 1667 at a meeting of the Royal Society in London, when, in order to carry conviction to others, those who had seen them signed a document to that effect for the benefit of others. The creatures thus observed were noticed in different kinds of infusions from which they get their name "Infusoria." What these early observers actually saw were some unicellular, lowly creatures, and a number of what we now know to be spores of plants.

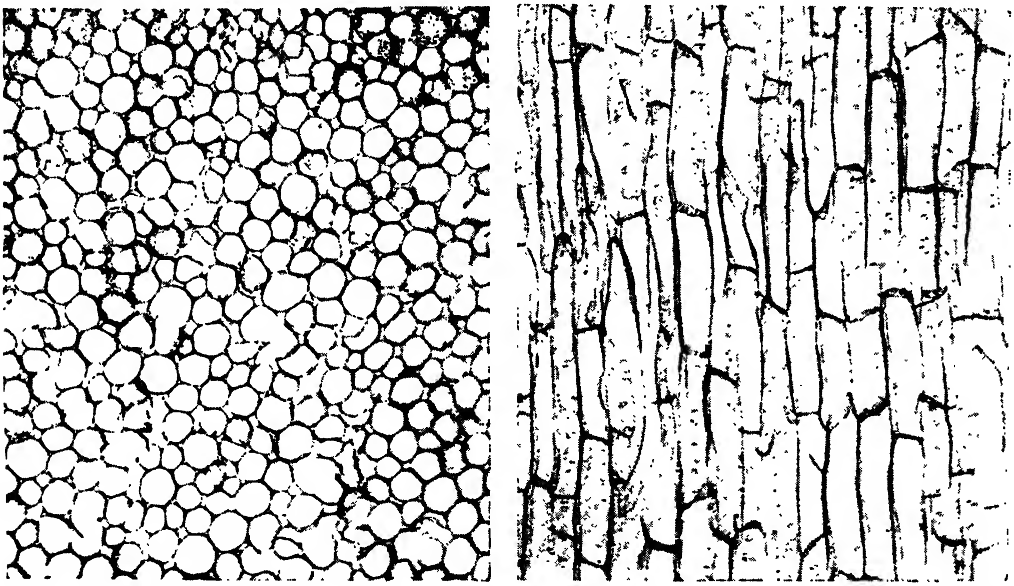
From this time onwards study under powers of magnification became the rule, and very soon observers discovered the special structures in leaves, and stems, and wood; and because these structures suggested to them the appearance of honeycomb they gave them the name of "cells." At that early time it was the walls of these cells to which the chief interest attached. It was not yet suspected that the materila which filled the honeycomb—the honey—was really the important thing. The structures were observed to grow, but how, was not known.

Then at the beginning of the nineteenth century it was noticed that the contents

of some of these cells were sometimes extruded into the surrounding water, that these contents looked like little masses or globes of jelly; furthermore, some of these masses were observed ultimately to come to rest and grow into filaments and other structures; and so the distinction gradually came to be recognised that the cell consisted of two parts as a rule, the outer portion, or cell-wall, and an inner, softer material of a slimy or gelatinous nature. This latter apparently lives in the cell, much as a snail lives in its shell. Sometimes it shows no parts, but is homogeneous, but in other cases it was found that it could be differentiated into quite a number of parts, such as threads, nodules, and so forth. Many of these facts were discovered by Mohl, of Tübingen, who, in 1846, applied to this gelatinous viscid substance, which filled the cell as the honey filled the honeycomb, the name of "protoplasm." Hence arose these two terms which from that time onwards have been the centre of such an immense amount of work, the cell and cell-protoplasm.

A more recent name, but one to which we must attend, has been given to all those little organisms which occupy cells made by themselves. This name is "protoplasts." These protoplasts may live as single individuals, and many do so, and, on the other hand, they may be aggregated together in great numbers so as to form the arrangement suggested by the honeycomb. In this latter case, however, it is to be noted that between the individual protoplasms there are frequently channels or spaces, and in other cases the protoplasms, or cells, are joined together by a kind of glue or cement, which the botanists term "intercellular substance." When this substance is separated and the cells brought apart, then we see that each cell has its own complete envelope.

Thus the most accurate conception we can give of cells, and collections of cells, is to regard them as analogous to the shells of some living animals, either solitary individuals or associated together in groups, and attached to each other. When this latter condition obtains, some of the protoplasts are set apart for one function and some for another. The development of new cells goes on inside those already formed by their own activity, so that the protoplasts are not only the building, but they are the building materials and the builders all in one.



HIGHLY MAGNIFIED TRANSVERSE AND LONGITUDINAL SECTIONS OF THE VEIN OF JERUSALEM ARTICHOKE, SHOWING CELLULAR TISSUE

This is an essential conception of protoplasm which we must make clear in our minds, because it is this very fact which alone distinguishes organic from inorganic substances. Thus the work of these living cells includes the duty of collecting and absorbing nourishment, so making possible the phenomenon of growth, the maturing of further generations of cells, the choosing

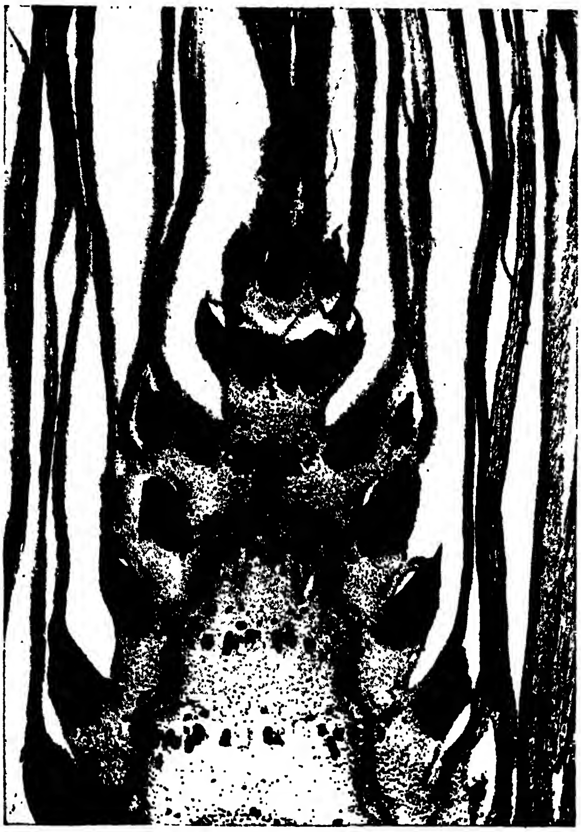
of their environment, and their protection from injury. In other words, all the duties of life for a living organism are ultimately thrown back upon the cell and its contained protoplasm.

Amongst the various properties which this wonderful substance has is that of motion—it is a motile substance. It can be observed to change its shape at will, and sometimes single protoplasts are furnished with hair-like organs, or cilia, which are also means of movement. They are not, however, necessary for this purpose. Protoplasts can change their outlines by simply projecting parts of themselves in one direction and withdrawing other parts. This gives a sort of creeping movement and is particularly noticeable in what is termed "naked protoplasm"—that is, in protoplasm which is not confined within a cell-wall.

Protoplasm, however, also moves when it is within a cell, but in this case, of course, its movements are limited by its walls. As the cell-wall grows the protoplasm within clings to it, and should it not increase with equal rapidity, spaces or vacuoles are left within it. Currents are observed also within cells, actual streams of protoplasm. In short, quite a number of various movements may be observed to go on within the cell under high powers of the microscope.

The result of the growth of the cell-wall is that the protoplasm which sticks to that wall stretches across the empty spaces within in the form of threads or strands.

Along these strands there may be seen at times a definite movement backwards and forwards of small dark granules, which serve to make plain the direction of the current. Other particles in the protoplasm, such as the green colouring matter in plants, appear to be unaffected by these movements and remain still. In other words, the protoplasm appears to pass over these granules. It is from observations such as these that we learn that the protoplasm within the cell is really divided into two parts, an outer somewhat tougher portion, and an inner more mobile part, these being termed respectively the "ectoplasm" and the "endoplasm." It is within the latter, of course, that the moving granules and particles are seen.



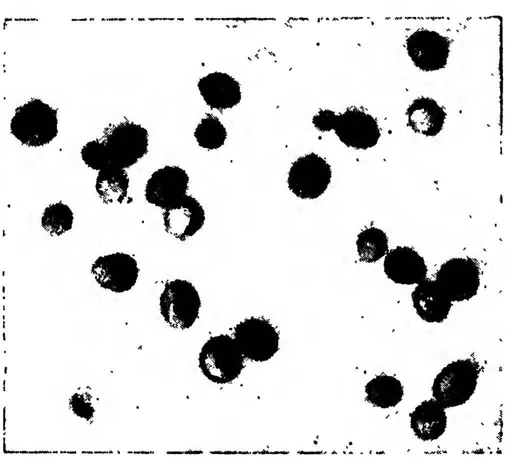
THE GROWING POINT OF HORSE-TAIL

Similar movements and others may be observed in connection with the protoplasm of unicellular creatures, which in addition, however, occasionally show a movement of two individuals towards each other which actually fuse together on coming into contact.

It must not, however, be supposed that all cell protoplasm is of exactly the same constitution. In fact, the minute study of its behaviour in different plants and different cells has forced observers to form the opinion that there is such a thing as what is called "*the specific constitution of protoplasm.*" This phrase requires a word or two of explanation, and the idea that it is intended to convey is one which we must endeavour to grasp. It is found that the protoplasm of different kinds of cells requires for its nourishment and growth different particles or elements which it is able to abstract from its surroundings. It is because of this specific character evidently that protoplasm is able to build itself up into the great variety of tissues and

organisms in which it manifests itself. In other words, protoplasm has a *constitution* rather than a composition. The former term implies more than the latter. True, it is composed of certain chemical elements, but that is not the whole truth. The protoplasm of different plants, although so composed, exhibits the differences we have mentioned—that is to say, it is *constituted* differently in the different species. Hence it is more accurate and more explanatory to speak of the constitution of protoplasm rather than its composition.

The chemical formula can be given for the composition of protoplasm. True, but no chemical formula can be given for the protoplasm of different species of plants. Each protoplast may be said, therefore, to represent an organism which contains many chemical compounds, and these it can renew when necessary, and modify their arrangements in response to the environment. There is, however, undoubtedly some very minute and intimate structure in protoplasm, enabling it to perform its complicated functions, which is at present beyond our knowledge, but which is best expressed by saying that protoplasm has a specific constitution.



A YEAST PLANT BUDDING NEW CELLS

So infinitely delicate and minute, however, must be the ultimate structure of living protoplasm that it is not certain we shall ever be able actually to see the mechanism itself which builds up the living part of the cell. The mental picture which we form, therefore, of the smallest masses of protoplasm must be largely theoretical. Not so, however, their results, because we can actually see what this protoplasm does—that is to say, there is such a thing as its visible constructive activity.

This watching of protoplasm at work is best seen in the large single-celled bodies of the lowly group of organisms called the "myxomycetes." One of these lowly organisms is that which may be seen in the shape of a sticky yellow mass on the dry bark of the branches of fallen pine-trees, where its appearance suggests that of yolk of egg. This covers a large portion of a branch in a thin layer. If this mass be watched during the hours of darkness, a most remarkable change is seen to take place in it. Instead of being now a smooth, slimy covering, it is observed to change its form in certain places into a number of warty projections, giving the whole thing a coarse, granulated look. Towards morning, from these lumps small pear-shaped bodies on stalks make their appearance, and the lumps themselves are no longer sticky or viscous, but have become a mass of fine hairs, or threads, with numerous minute black spores lying between them. This whole process takes about twelve hours to accomplish.

Other organisms of this same group go through a similar series of changes, resulting, however, in quite different shapes, so that we here have what we called an example of the visible constructive activity manifested in protoplasm, an activity the results of which are quite obvious to the unaided eye which may be watching them, ultimately caused by a mechanism so delicate as to be invisible to the strongest microscope.

Where there is a cell-wall surrounding the protoplasm, it frequently behaves very like the skin of an animal rather than as a rigid covering. That is to say, it does not hinder the movements of the protoplasm within, or its changes in shape, but it adapts itself to them, even though it may take no part in the actual process of growth. Sometimes it perishes as these are completed; in other cases it remains changed in aspect with the protoplasm itself.

It is on account of these constructive activities of protoplasm that we find in other plants than those just mentioned the processes in protoplasm known as segregation, gemmation, and cell division.

In segregation, the protoplasm divides inside a rigid cell-wall, into a number of separate portions all exactly the same shape. No partitions are formed in the cell, but new cell-walls are formed by each separate mass of protoplasm within for itself. In

this way sometimes more than a thousand small bodies may arise inside one cell, each ultimately having its own wall. Naturally, the larger these are the fewer the number, and vice versa. Moreover, they vary immensely in shape. They may be round, oval, pear-shaped, thread-like, straight, spiral, or twisted, and so forth—another example of the visible constructive activity of protoplasm.

Gemmation differs from segregation in that here a portion of protoplasm is protruded from the general mass like a bud, which gradually increases in size until it is as large as that from which it originally protruded. Eventually, the bud and the original mass separate. This is typically seen in the yeast plant.

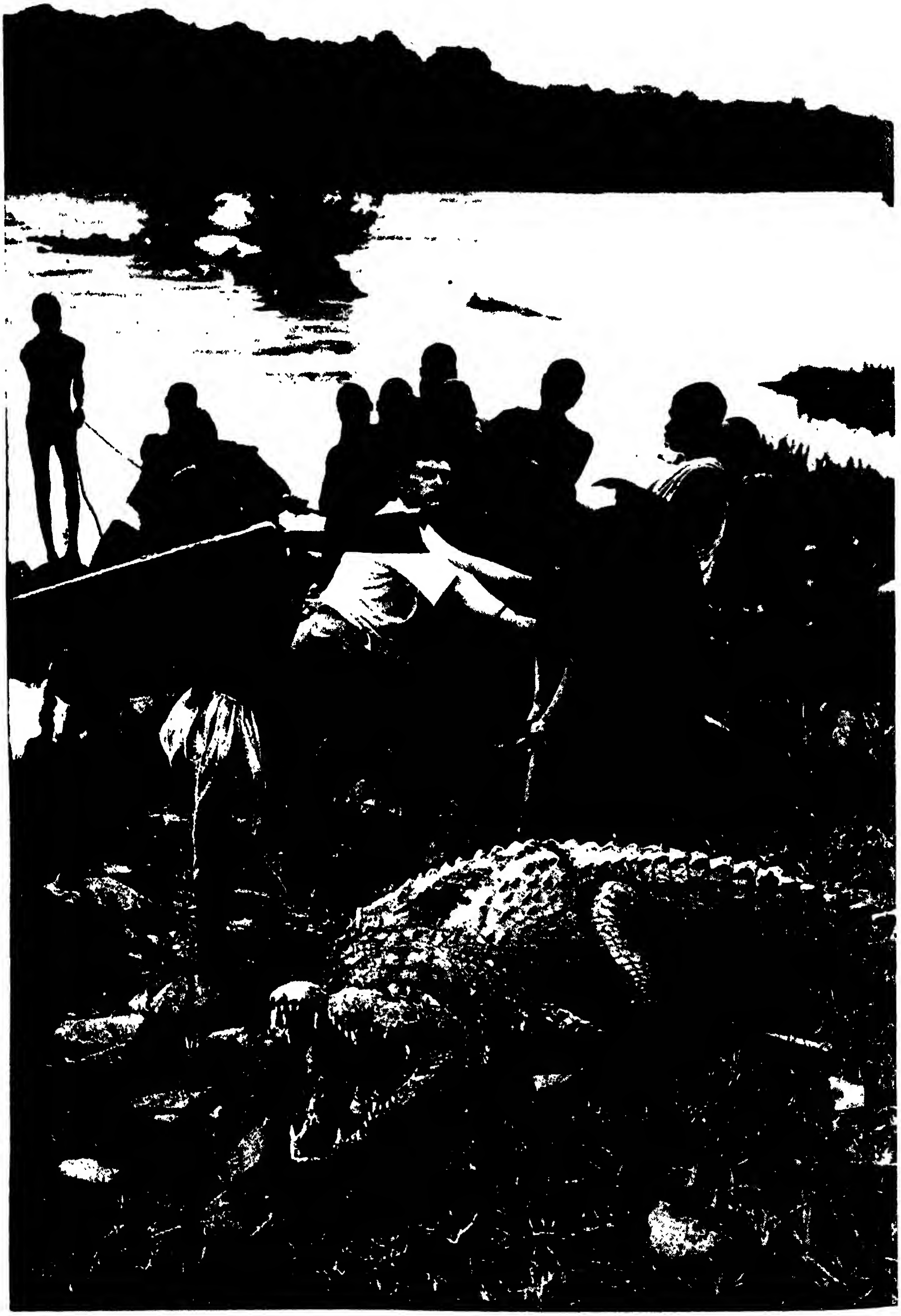
In true Cell-Division the protoplasm within the cell develops a partition, within which ultimately divides the protoplasm into two halves, so that two chambers, or compartments, are produced. By successive repetition of this process we obtain a multicellular organism, such as any of the higher plants or animals. The details of this very complicated process—that of cell-division—have already been described in an earlier chapter in the section on "Life." We have, therefore, perhaps said sufficient in this place to give some idea of the nature and composition of this extraordinary substance, protoplasm, and its properties as manifested in the lowliest plants. We shall have to say some more on a further aspect, however, when speaking of reproduction in connection with seeds and fruits.


MYXOMYCETES WITH SPORE-BEARING HEAD

The earliest systematic attempt to produce an account of plant life may be said to be that of Pliny the Elder, who is supposed to have been born A.D. 23, in Italy. Throughout a very varied career he was a distinguished student, and a most painstaking compiler of facts which came under his notice. According to his nephew, Pliny died as the result of an eruption of Mount Vesuvius, from which he was suffocated. Amongst all his works, only one remains, namely, his "Historia Naturalis," or "Natural History," which consists of no less than thirty-seven books, the first of them being a table of contents of the other thirty-six. These contents are of wonderful variety, including the elements, the stars, the winds, the geography of the world, the organisation of man, notable characters, inventions, a system of zoology treating of birds, fishes, insects, and man; and then sixteen books devoted to botany.

These may be said to be the origin of botanical science. In them Pliny gives an account of the various trees, herbs, fruits, etc., and the medicines and drugs which were obtained from them. It is only right to say, however, that this large work is by no means to be regarded as the result of the thoughts and observations of the writer. It really consists chiefly of facts or suppositions which he, as the result of immense industry and reading, had found to be recorded by all the various authors whose works he had come in contact with. From all of these he has selected just what he liked without much system or judgment, so that, from the strictly scientific point of view, the work is not of great value, except, possibly, from its geographical side, and from the historical point of view. Nevertheless, it remains as the earliest effort to reduce natural history to a science.

CROCODILE-HUNTING ON THE UPPER NILE



MEN OF THE KAVIRONDO TRIBE IN CENTRAL AFRICA WITH A CAPTURED CROCODILE

ANIMALS IN ARMOUR CLAD

Defensive Survivals From the Ages When Jaw and Claw Ruled the Earth

THE CROCODILE AS A GRUESOME RELIC

THE scheme of life is arrayed upon a world-wide battlefield, ancient as the hills. The war is for a place in the sun, for a place in the shade, for a place in the water, or a place in the air. The war is in progress wherever there is life, a war which reveals itself in actual deadly combat, or progresses unseen, or is traceable only in the less obvious operations of the struggle for existence. Every order in life sets out upon its career as a traveller arming for a road beset by bloodthirsty brigands. The process is so old that life may be said to have organised itself into three campaigning groups. One makes attack its means of defence and its method of maintenance of existence. A second trusts to speed, to agility, or to that deceptive appearance which we call protective mimicry. This, of course, is now the largest group, and is susceptible of infinite subdivision. The third great division lays on armour as it were a garment.

Though placed third in our classification, this group is really a primitive one. When the early animals, waxing mighty in numbers and potent in strength, emerged from the waters to the margins of seas and rivers, and spread far over the land, and the fight for food necessitated the devouring of animal by animal, some defence was called for which ravening teeth and claws could not penetrate. We see to-day in the armoured animals of our own time living relics of that gross and terrific past in which giant brutes, rending and tearing their living prey, parted the planet among themselves.

The armoured animals are comparable with a frightened city before which a hostile host suddenly appears. The first thought of the garrison is present defence, immediate safety, at whatever cost. They barricade every point of ingress; they gird themselves about with defences. So long as they keep the enemy from breaking in, it matters not at the moment that there is for themselves no going out. And the primitive beasts upon which the early carnivora preyed girt themselves with armour which preserved them from tooth and talon, and then rested well content. In time a garrison, if it is to escape death of inanition, must have recourse to other means than passive defence; its higher spirits must put behind them bastion and bulwark, moat and mound; they must take the open against the enemy, where brains and valour, or it may be speed in flight, shall avail to save their lives. Those that thus fight their way out of their self-imposed prison may live to people the earth, while besieged and besiegers may die where they rest.

The analogy holds in the story of the armoured animals. Nearly every group which can be traced back to its ancestors interned in the rocks is found to have attained either to nightmare proportions or to armour. Even the pariasaurus, an important link in the reptilian chain of mammalian ancestry, was mail-clad like a modern crocodile. Miles upon miles of roads in Russia to-day are paved with deposits in which this inestimable relic had become fossilised, but the implement of the geologist has now laid bare the armour in which this ancestor of warm-blooded, milk-giving animals was invested.

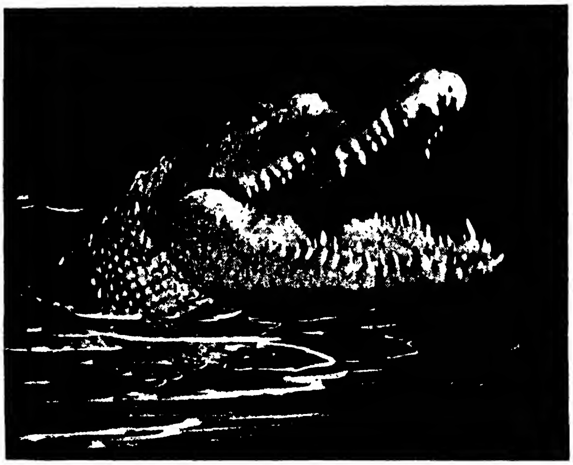
Man himself, far on in his history, had recourse to armour. He clad himself from head to foot in steel; he fought in chain-armour or mail, and hid his battle-steed beneath a cover of steel. But so-called chivalry, with its absurdities and armour for man and horse, went out with the arrival of gunpowder. The armoury at the Tower of London shows many a steel breastplate penetrated by the bullet of the man-at-arms. So, as death is just as complete in

armour-plate as in a woollen jerkin, and considerably more expensive as to preliminaries, the armourer of man lost his occupation, transferring his energies, centuries later, to war-vessels. Wellington, asked if the French cuirassiers had not "come up well" in a certain battle, replied: "They went down better, and when they were down they lay helpless upon their backs, like sheep." The breastplates of our Guardsmen are merely frippery for show purposes, of which the men are divested when the real business of their calling arrives.

Most of the animals that retained their armour went out of the plan of existence. Why so many should have perished, while others have remained to flourish in enormous numbers down to our own day, is a problem which consideration of space prevents us from discussing. Armoured animals are more numerous than at first sight appears, for many types of insects in their coats-of-mail—all the crustaceans, the bulk of the molluscs in their shells, the coral within its defence, the starfish in his limey walls, the snail in his wondrous shell—these are all armoured as truly as are the mail-clad sturgeon and the heavily defended garpike, the coffer-fish, and the file-fish. But, numerous as are the animals which have survived by the use of material shield and buckler, they are in a minority as compared with those that have become extinct, yielding place to unarmoured descendants for whom activity of brain and limb proved a better defence than the finest mail or carapace that Nature ever designed. It will be of interest to consider the defences and habits of some of the survivors, and, neglecting scientific classification, include diverse types.

It is one of the delights of the anatomist to be able to indicate structural features common to birds and crocodiles, but the fascinating fact to the layman is the resemblance between the two in the matter of their birth. Among the members of the crocodile order we have animals which in point of length exceed all other terrestrial animals, snakes alone excepted. Some of them attain a length of between thirty and forty feet, and huge girth and bulk. Yet these monsters lay eggs—forty, fifty, sixty eggs to a nest. In the structure of the heart, and in the beginning of a diaphragm dividing the thorax from the abdomen, the crocodile is more highly specialised than any other reptile, yet it has not advanced to the viviparous stage.

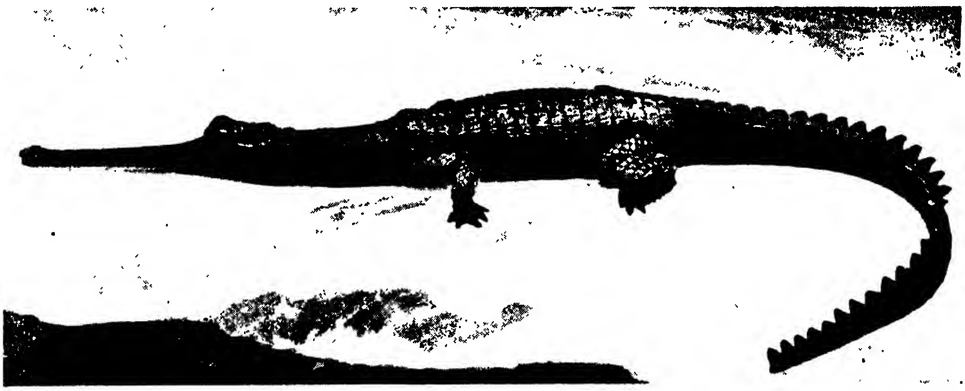
There are reptiles, the vipers, for example, as there are certain species of shark, in which the eggs are hatched within the body of the parent, but the lord of all the reptiles, the strongest thing in armour, is hatched from an egg laid in an earthern nest, or in rotting vegetation underlying the bushes upon the verge of stream or swamp. Fancy a thirty-five-foot monster, capable of living hundreds of years, and of slaying horse, buffalo, rhinoceros, and man himself, issuing from a little pit of sand as the product of an egg no bigger than that of a goose! This is a fact to carry the mind back to the dim and distant ages when fiends in the form of animals made life hideous.



THE TERRIBLE JAWS OF THE CROCODILE

The crocodiles have survived because they remained more generalised than other armoured monsters. Their armour is of horny plates, extending from the head to the tip of the tail, and, considering the mobility of the animal, this is practically the best form of armour preserved. The crocodile has one disability. Thanks to a merciful limitation, the brute cannot turn its head from side to side, but must charge in a straight line, so that a victim having the presence of mind to circle round the reptile can escape. But, despite this limitation, the group has long been lord of the places which it frequents. Fairly active on land, and equipped with formidable rending teeth, cunning, invincibly ferocious, and impervious to the attack of any living animal, the members of the order have thriven wherever climatic conditions have rendered it possible. They positively teem

in the waters of Central and Southern America. The Amazon, in parts of its course, is as well stocked with them "as a ditch in England is with tadpoles in summer." They are at once the scavengers and the scourge of the Ganges; they grow to huge size in the Nile, but not now in the lower reaches of the river accessible to the sportsman. They abound in certain rivers of China; they are the curse and horror of certain African rivers. They are one of the indigenous terrors of Australia. In tropical and sub-tropical climates, given the necessary river estuary, lake, or marsh, they have defied every animate rival throughout their career. What has given them this great ascendancy, this hold upon life and power during the ages wherein life about them has changed like the moving colour-scheme of the kaleidoscope? Clearly armour has been of service to them. No animal can prevail against such an equipment. Added to this is the power of the animal to live either in the water or out of it, a circumstance associated with a highly important fact in regard to the gaining of food. It is not to be inferred that a crocodile can sleep under water day after day, or night by night, never rising to the surface. It is not a gill-breather, of course. But the beast is so fashioned that, while its entire body is immersed, the nostrils, elevated above the rest of the snout, remain free of the water and enable the animal freely to breathe while thus hidden. That is one means by which it is able to capture its unsuspecting prey. But the breathing process is peculiar in more than this respect. The windpipe is not open to the mouth as it is in other animals: it is continued into the nostrils, and can be entirely divided from the mouth. The consequence is that, seizing its prey and dragging it under water, the crocodile can breathe with its mouth open without hindrance from the water by which its tongue and jaws are flooded. The victim drowns while the cruel teeth hold it under the stream, but the reptile, so long as the tip of the muzzle remains in the air, can breathe with ease. This is a marvellous adaptation to the life which this reptile of the world of waters lives.



THE GHARIAL CROCODILE, WHICH CAUSES TERRIBLE LOSS OF LIFE IN INDIA *Photo, C. R. Walter*

A MISSISSIPPI ALLIGATOR, BELIEVED TO BE NEARLY 200 YEARS OLD

The fact is that until the coming of powerful firearms there was nothing to check the advance of the crocodile. Perhaps it was, from certain points of view, as well, for if it took toll of human life, the crocodile also acted involuntarily as a life-saver, in that it has been for ages the great scavenger of the waters, consuming for preference the putrid bodies carried down by streams in flood which might otherwise have poisoned man's drinking-supply and spread disease.

So far only the generic name, " crocodile," has been employed, but the order embraces half a dozen genera and close upon a score of different species. The caimans are restricted to Central and South America, and are so numerous that the pursuit of them has become an organised industry in Colombia, where as many as 30,000 skins have been exported in a year—a number which, it is said, could easily be raised to 100,000 a year, seeing that there are 4000 miles of rivers upon which to draw, only 300 miles being at present worked. The females of the Colombian reptiles, it is stated on expert testimony, each produce 100 eggs per annum. They prove devoted parents, displaying their solicitude in a manner which has not been elsewhere verified. So far from eating their young, they carefully conduct the latter from their nests to the water, and there open their jaws for the little ones to rest upon and to use as diving-boards. Some of the animals attain a length of twenty-four feet, and a girth more than six feet; while their skins of mail, half an inch in thickness, not counting the underlying bony protection, cover, when spread out, an area of from eighty to ninety square yards.

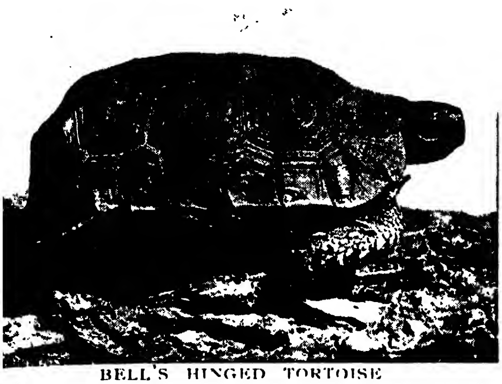

ALLIGATORS JUST EMERGED FROM THE EGGS

The species most sought, however, is the shorter, thick-headed caiman, whose length does not as a rule exceed ten feet; but as it yields excellent ivory in the form of huge teeth, as well as some 80 lb. of fat from which a fine, clear oil used by the natives for medicinal purposes in place of cod-liver oil, and the bones and flesh have a value to the agriculturist, there seems a future for the king of the reptiles very different from that dreamed by the natives whom he has so long terrorised. The caiman is called the alligator, but scientifically the alligator is a genus consisting of only three species; and the curious thing is that one of these, the Chinese alligator, is that which most nearly approaches the American caiman in structure.

The crocodiles proper are more widely distributed than the caiman or alligator, being found in Asia, Africa, and tropical America. Livingstone had many unpleasant experiences of crocodiles, which he wrongly calls alligators, a name also given wrongly to the crocodile of India. Livingstone describes how he saw a bearer of his suddenly seized by one of these brutes in the River Leeambye. The man kept his head, and when the brute had got him down to the bottom of the water, whipped out a serviceable dagger, and stabbed his assailant behind the ear—the only spot in which one of these creatures can be instantly killed. But the blow must be delivered by a bullet. In this case the reptile was only wounded. Still, writhing with pain, it released the man and made off at a great rate. But it left wounds upon his thigh which the man would take to his grave. Certain African tribes have a morbid horror of the crocodile and all its works; and if one of their number be bitten, or even splashed, by such a creature he is forthwith, with his wife and children, expelled the tribe. One such unfortunate outcast engaged with Livingstone, but, fearing that the traveller would regard him with aversion and contempt, refused to tell the cause of his expulsion. But it was there, written in indelible characters by the teeth of a crocodile upon the luckless man's flesh.

This attitude of the Africans curiously

REPTILES THAT ARE ENCASED IN ARMOUR

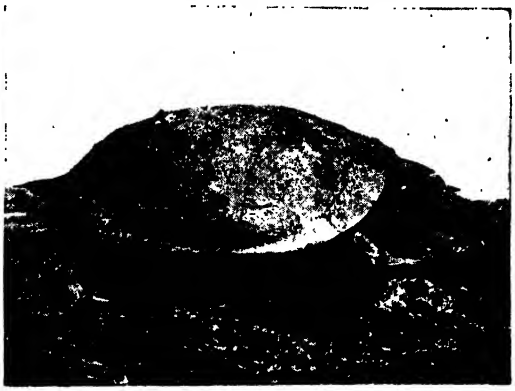


BELL'S HINGED TORTOISE

CAROLINE BOX TORTOISE

MARION'S TORTOISE, ONE OF THE OLDEST AND LARGEST IN THE WORLD

THE LEATHERY TURTLE



THE ELEGANT TERRAPIN

suggests a survival of animal worship which has its counterpart in India, where terrible loss of human life results from the gharial (incorrectly written "gavial") and the ferocious estuarian crocodile, a brute which ranges from India, Ceylon, and Burma, right away to Australia. It is the habit of a certain type of mind to worship the powerful and terrific. Grant Duff found a temple erected in India dedicated to cholera. Naturally, then, the frightful crocodile is regarded as sacred—as it was, in ancient days, in Egypt. A typical example is afforded by the little village of Mugger Peer, not far from Kurrachee. Here is a ford at which it was noticed that men, women, and children, crossing with their burdens at eventide, were wont to disappear. So a watch was at last set, and it was found that the crocodiles which infested this part of the river were the offenders. The Government were petitioned to intervene, not to destroy the animals whose crimes had made them sacred, but to restrain them. So the crocodiles of Mugger Peer are, to this day, restrained; enclosed, so far as this ford is concerned, by high walls. But the largest and most ferocious brute the people worshipped with particular fervour. He was the rajah of the crocodiles, they said; he must be left at liberty. And this course was agreed to, on the condition that, night and day, a sentry kept guard to watch the reptilian rajah, and to see that he did no harm. And a little white temple has been erected at Mugger Peer, whose congregation make it their business to feed the crocodiles, that they may not suffer hardship for the loss of the human flesh to which they formerly helped themselves without stint.


THE HAIRY ARMADILLO *Photo, Lewis Medland*

Of course, the tables can be turned upon the crocodile; not only may his skin and his fat be utilised—his flesh *can* be eaten. Dean Buckland was not the last to prove that fact. When he got a couple of the monsters taken down to Oxford, he first tested the truth of Waterton's story of riding one with its forelegs turned back, and found that the statement was feasible. Then he slew and dissected his pets. From one he cut a steak, and made a dish of it for a dinner-party. All the guests decided that the flesh was excellent, resembling tunny or sturgeon. Now, an old servant of the university watched with hungry eyes, aged "William," who looked after the anatomy school, and presided over the skeletons, particularly the skeleton of a murderer whose remains he venerated. And old William, when the guests were gone, took crocodile flesh for himself, and in the middle of the night roused the Buckland household, crying: "Oh, that crocodile—oh, that crocodile!" He was almost at the point of death when the good Buckland went to his assistance. Perhaps it was not to be wondered at, seeing that he had set his aged digestive system the task of grappling with enough crocodile steak to have made a plethoric meal for five stalwart trenchermen.

But it is not as a meal that we think of this knight in armour. We think of him rather in his ancient and accustomed rôle of stealthy, voracious demon of the wilds, who, with a snatch of his appalling jaws and a lunge with his giant tail, pulls under water man or animal, and has been seen stealthily to wait in the rear of a rhinoceros; then, as the pachyderm was leaving the water, to fix its frightful teeth in the animal's hind leg, and, after a protracted struggle, draw the monster back into the stream, and drown it.

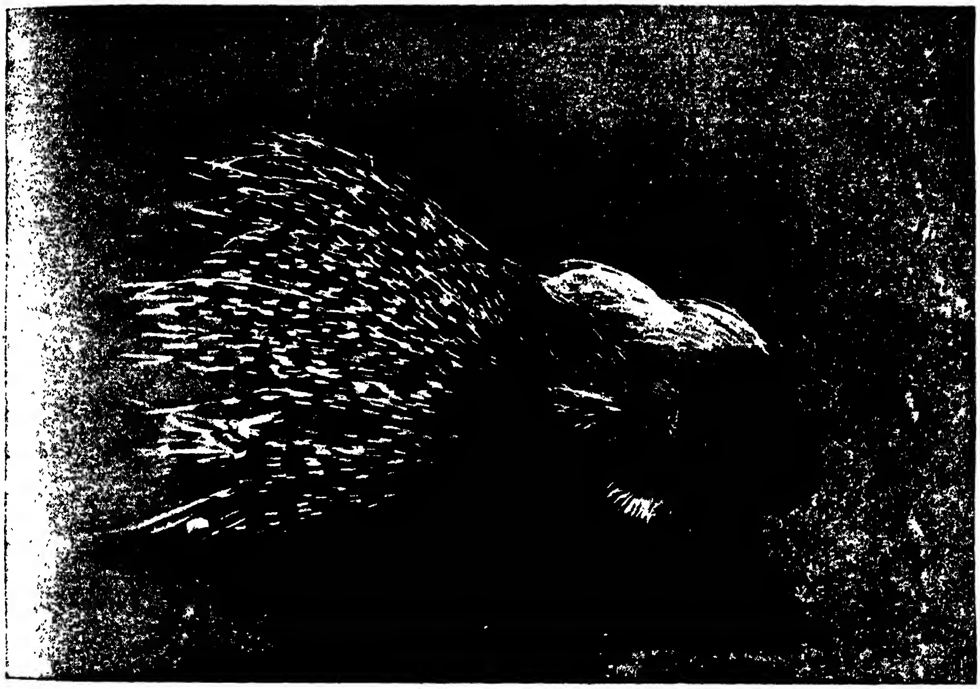
Though its brains are of the most contemptible order, yet there is deadly cunning in the crocodile's ways, as when, seeing a man upon the bank of the river opposite to that on which it rests, it plunges like a fury beneath the water. All is silent, but a keen observer may detect a line of ripples advancing across the water. The brute is rushing along the river-bed to seize the man, who has lost sight of it. The adult crocodile has no enemy to fear except the man with the gun. It has only one friend, and that is the black-backed plover, which,

walking unconcernedly into the open mouth of the animal, scavenges without molestation, and warns the reptile, on the approach of man, with its cry of "Zic-zac" from which the bird takes its name.

Before taking leave of this order we ought to recall the fact that the gharial and the alligator formerly abounded in England. This is the more notable from the fact that nowhere on earth to-day can the two genera be found together. One is restricted to tropical Asia, the other to the warmer latitudes of America, and both are excluded from Africa, in whose waters only the crocodile is found. As Owen has written, not one representative of the crocodile exists naturally now in Europe, yet every form of the order once flourished in close proximity to each other in a land that now forms part of England.

We shall meet other armoured reptiles at a later stage, but here we pass to an extraordinary development of the defensive principle upon totally different lines.

The crocodiles may be likened to armoured trains, but the tortoise family are rather perambulating forts—minus guns. We mourn, and rightly mourn, a lost species, but this family is witness to the fact that contemporary marvels, so long as they are plentiful, receive not a tithe of the attention that they merit. It is a plain fact that there is not in existence to-day, nor embedded in the matrix of the rocks, a more extraordinary animal than the tortoise. Here defensive development has reached its most fantastic expression. There is something almost uncanny about this animal. It began, as we suppose, upon lines followed by crocodile and many an extinct monster of the sea and land, with a leathery hide in which were embedded various nodules of bone. From these has been evolved one of the most wonderful armaments ever devised. The nodules became plates of bone welded into an impregnable carapace. Superimposed upon this has arisen the beautiful overshield of horn. To attain this end the tortoise has, as to most species, sacrificed the skin of its trunk and the underlying muscles; it has forfeited all elasticity of vertebræ between the neck and the tail, and fused these vertebræ into an immovable hollow column of bone, incorporated, like the ribs, into the fabric of the carapace. It has gradually thrust collar-bone and hip-girdle out of place, so that these lie now, in the adult, not outside and free of the ribs, but within the cavity which they form. Teeth have gone, and a bird-like beak remains. Breathing is conducted by



THE COMMON PORCUPINE

specialised organs; and in some of the water-tortoises the reptile is developing a fish-like method of supplementing its supply of atmospheric air by extracting oxygen from the water by means of special areas richly charged with blood-vessels over which a supply of water constantly washes so long as the creature chooses to remain beneath the surface.

As we all know, there are giants even among tortoises. They were formerly abundant in India, Egypt, North and South America, and in parts of Europe, but the advent of man was too much even for the ultimate height of animal armour, and their range became restricted to certain oceanic islands, such as the Seychelles and the Galapagos, where they proved so attractive a diet to mariners that they have been practically exterminated. The survivors should be preserved as if they were the last of the world's diamonds, for man will never again see another such natural marvel.

It is common knowledge that a tortoise is one of the longest-lived of animals. One died at the Zoo recently that was believed to be between four and five centuries old. How long they can live no man knoweth. The question arises, then, how do they continue to grow for such a length of time without casting their armour? The scheme of armament is never broken. The bones of the carapace are not one indivisible mass, but are sutured beautifully together in such a manner that growth and expansion continually take place. The fortress grows with the garrison. It really is a fortress in the true sense of the word, for there are tortoises that have the lower half of the protecting armour hinged so that at will the head can be enclosed as by an ascending portcullis, while others are similarly defended both fore and aft.

Even so well accoutred a creature as the tortoise must find food; and the stress of life drove early members of the group into the water, where turtles and water-tortoises developed. It would spoil a city gourmand's appetite, perhaps, to tell him that his favourite dish is reptile broth, but his soup is only the stew derived from boiling a sort of water-tortoise which we call a turtle. In this family the legs have become flappers, and, correlated with the carnivorous diet, a more formidable beak has been evolved, with which a turtle can snap off the fingers of an incautious man's hand as easily as a land-tortoise can breach a crisp lettuce-leaf. The most formidable of these are the snappers and the alligator turtle, one of the latter having been known to bite a piece out of an inch plank. The tortoise-shell of commerce, by the way, is derived from a turtle, the hawksbill. Disgraceful barbarity was formerly practised in procuring this substance, the shell being burnt off the back of the living reptile, but happily that abomination has long been banished, and the trade purged of cruelty.

THE SHORT-TAILED PANGOLIN

When Frank Buckland was made to pay three shillings and sixpence for the carriage of his monkey, which, according to railway regulations, was a "dog," he asked the porter what he must pay for a tortoise. "That's a hinsect and goes free," answered this prime naturalist. What would the glyptodon have been declared in such a court? It was a mighty beast, in a vast bony covering at least six feet in length, and of tremendous weight. Most of us would have been inclined to describe it as a reptile, but in reality it was a mammal, and it has left collateral mammalian descendants in the armadillos of our own time. The glyptodon, the biggest armoured mammal that ever lived, was too massy, too immobile. The armadillos have improved upon the older method; they have their fine coat of bony mail, covering the upper parts from the snout to the tip of the tail, but they have their armour hinged, as it were, so that these sturdy creatures can curl up into a ball of armour as neatly as the most lissom of hedgehogs.

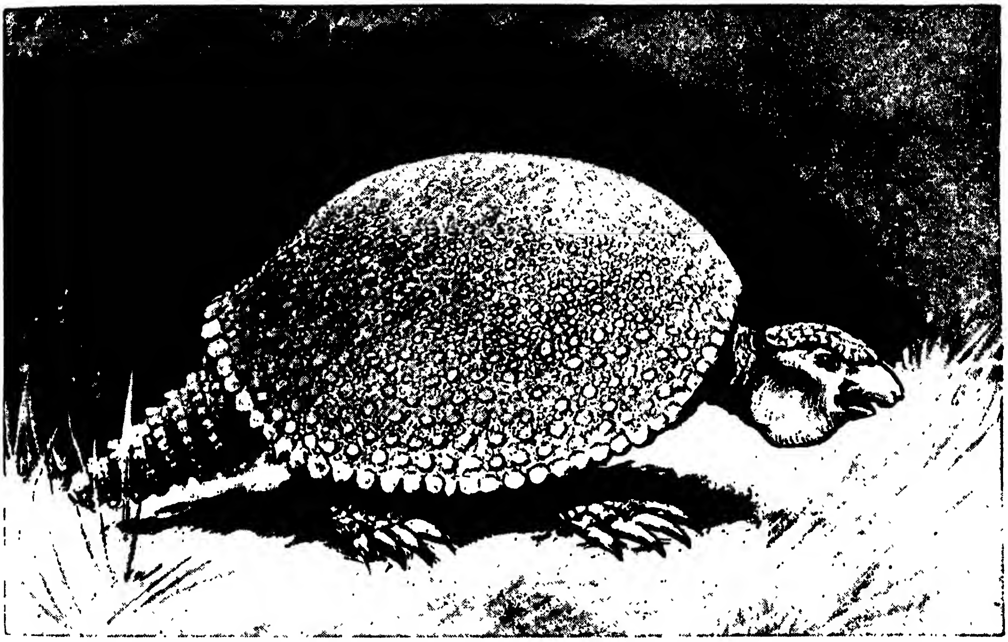
Their near ally, the pichiciago, lacks this advantage, and, though well armoured from buttocks to snout, must remain at full stretch when attacked. There are several species of armadillos, the type culminating in the great armadillo, a mammal marvellously armoured, three feet in length, and clad with claws formidable enough to

suggest an easy passage into the graves which the animal is accused of robbing.

Two other styles of armament come to mind in those borne by the echidna and the pangolins, the latter well described as animated spruce-cones with head and legs attached. They are toothless insect-eaters, ants being their chief source of food; but, as pre-natal evidences point to ancient possession of teeth, it is believed that the pangolins arise from the same stock with the armadillos. The name of the Echidna—spiny ant-eater—declares its characteristics. But though warm-blooded, it lays eggs, and hatches them in its pouch, and then suckles the young—so little and yet so far is it beyond the reptile.

omit to inquire. The Canadian porcupine, which has shorter spines than those of the typical group, has these implements short and loosely attached to the skin, so that in a scrimmage they easily become detached and fixed in the flesh of an antagonist. But in the larger porcupines of the Old World—they are found both in Southern Europe, in Africa, and in tropical Asia—the quills are longer and stouter, and are brought to bear by a wily device.

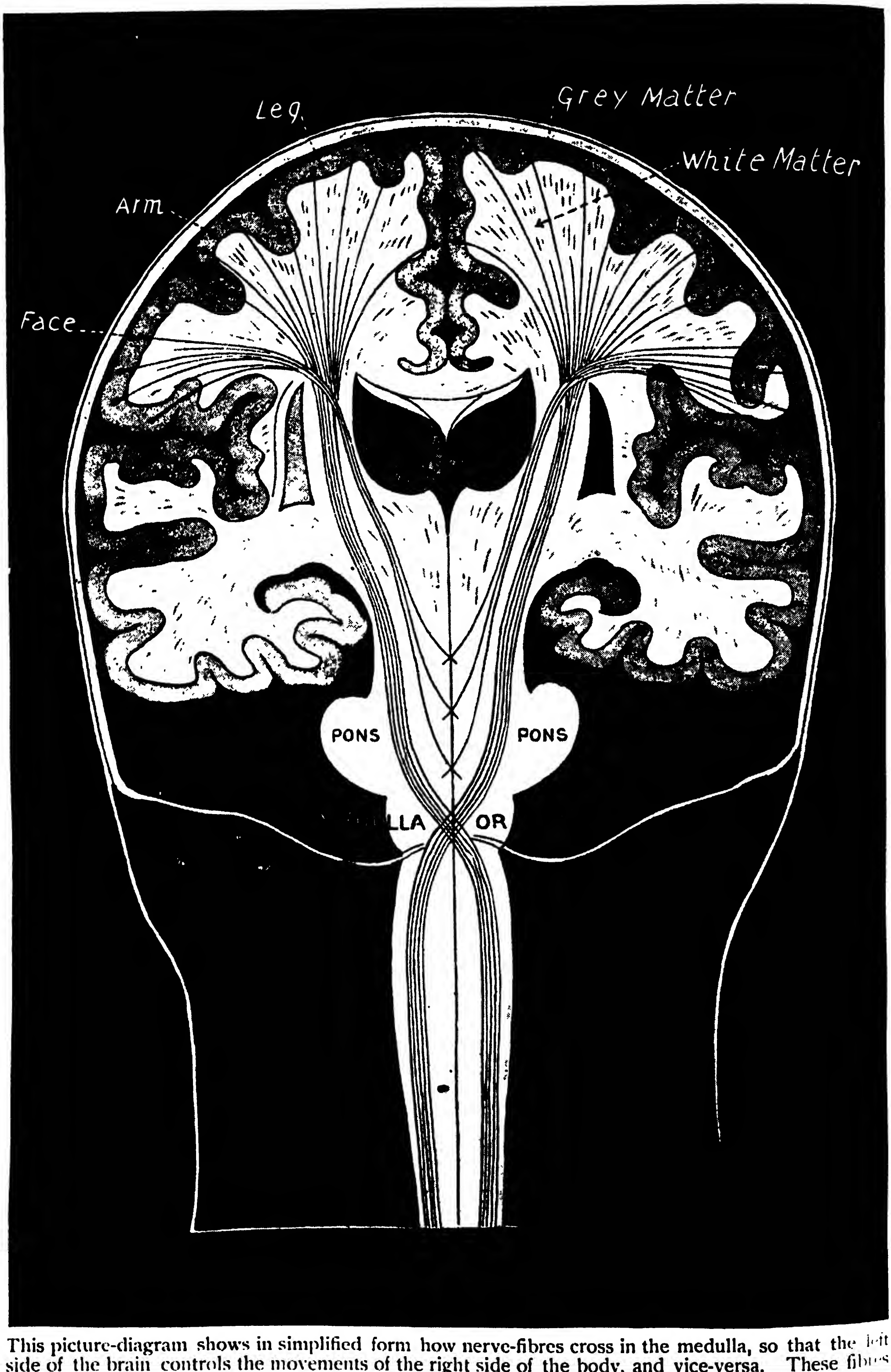
The porcupine, upon being attacked, keeps his hindquarters towards the enemy, and, making a sudden dash backwards at him, thrusts his quills deeply into the enemy's flesh. Should any of the quills be loose, they may then remain in the hide



THE GLYPTODON THE BIGGEST ARMOURED ANIMAL THAT HAS EVER LIVED

In the armament of the echidna we advance towards another scheme, that of the porcupines. We have finished with plates of bone and horn, and have reached the defence which furnishes means of aggression. Porcupines, whose name really means spiny pig, are common to both the Old World and the New, and are rodents. They are supposed to be the counterpart in the lower creation of the assegai-throwing Zulu, for nothing will shake the popular belief that the porcupine, when he is annoyed, stands still and bombards his enemy with his quills. Whence the motive-power for the discharge of the projectiles could be derived the authors of the legend of the antagonist, and so support the old story of assault by battery of quills. The Brazilian tree-porcupine has its spines hidden by hair, but, as they are barbed like the spines of certain cacti, no man handles this animal with bare hands. It is a curious but effective defence, a device resembling that of a man the hair of whose head was sown with fish-hooks. The defensive-aggressive quill has succeeded, too, for porcupines are widespread and many. But then the land-tortoise, most immobile of all Nature's armed host, is multitudinous in numbers. So are the crocodilia. Not all the best-defended have perished of inertia.

MESSAGE-CARRIERS FROM BRAIN TO BODY



This picture-diagram shows in simplified form how nerve-fibres cross in the medulla, so that the left side of the brain controls the movements of the right side of the body, and vice-versa. These fibres convey the impulses from the surface of the brain to cells in the spinal cord, and thence to the muscles

THE SUPREME ORGAN OF LIFE

The Design and Structure of the Brain, and the Supposed Functions of its Component Parts

A SUMMARY OF EVOLUTIONARY CHANGE

We have already studied the lungs, the liver, the heart, and many other organs of man, and have learnt that they exist for his nervous system, and, above all, for the supreme organ that life has created hitherto -that is, the brain of man. This organ is worthy of very careful study by means of the scalpel and the micoscope, for we should not forget that for many long ages, when men argued without looking, they believed that the function of the brain was to cool the over-heated vapours arising from the heart -a physiological theory which is still contained in many modes of speech, as when we say that we are "in high spirits."

Only the anatomy of the brain can afford us the clue to its function, and can justify those views of its essential purpose which have already been suggested. We are encouraged by the fact that this organ *must* hold the key, if anatomy holds it at all, to man's place in the world. It is the only characteristic organ ot man, being far larger and more complicated in him than in any other creature. It is absolutely the largest brain in the world, even including the whale and the elephant, and, relatively to man's size, it is larger and more exceptional still.

Further, we know that the size of this organ has been increasing, along the vertebrate line of dawning intelligence, for long ages past. If we compare any branch of modern mammals, for instance, such as the horse, the ape, the dog, with their remote ancestors, we find that the tendency has always been for brains to beat bulk, brains always increasing, while bulk very often decreases. This is the organ of intelligence, and therefore above all the organ of man. It is the highest achievement of organic evolution. We marvel, naturally enough, at the beauty and powers of bird and beast. We almost cower beside the skeleton of the whale. We are staggered at the size of early reptiles and mammals, such as those whose skeletons can be seen at South Kensington. We envy the dignity and longevity of the mightiest trees of the New World, and the elegant chemistry, incomparable in its way, of the green leaf anywhere; but each of us carries inside his skull, and is using at this moment, an organ, a material object, a piece of machinery, which beggars everything, extinct or extant, that Life has ever achieved since Life began.

The development of the brain in each of us is to be noted. At a very early stage in our history there is a long groove formed along the middle of the back--just where the backbone will some day be. This groove comes to be roofed in, thus forming a long, closed tube, lined, of course, with cells from the surface or epiblast of the embryo. This is the nervous or neural tube. The cells lining it become, or give rise to, nerve-cells. From these there spring the innumerable nerve-fibres which pass to all parts of the body for various purposes. The back part of the tube, which is the lower part in the erect attitude, remains small and straight. It is the spinal cord, with its tiny central canal, which is the original tube that was formed in the embryo when the neural groove was closed in. Around its central canal we see a multitude of nerve-cells, called the "grey matter" of the spinal cord, because they look grey. That is where we should expect to find them. Outside them is a quantity of "white matter," consisting of nerve-fibres, running up and down in the spinal cord, to and from one part and another. The nerve-cells in the spinal cord are almost wholly concerned with the sensori-motor arcs which we have already discussed, and upon which psychological theory has asserted the whole of the nervous system to be based. Of all this, which is simple in essence, and is not characteristic of man, no more need be said.

except to observe that from each segment of the spinal cord there runs, on each side, a nerve with two roots, and that, as Sir Charles Bell discovered early in the last century, the front or anterior root is wholly motor, and the back or posterior root is wholly sensory. This was a great discovery, which really laid the foundation for our modern understanding, or for any understanding, of the nervous system.

The Astonishing Development of the Great Brain in Man

But as the embryo develops, the head end of its nervous tube develops in marked contrast to the tail end. It begins to form a series of more or less hollow bulbs, with constrictions between them. The tube is still a tube, with a single cavity, continuous from end to end, but at the head end this tube now consists of quite large chambers, and the nervous tissue around them is very greatly thickened. At one time we can distinguish five of these swellings, at another three. They become squeezed and compressed against each other, as they enlarge, for they have somehow to find room in the skull. But the front bulb is far and away the largest, and there is no room for it any further forwards. It has no choice but to fold backwards on itself, so that it comes to lie upon all the other parts of the brain. This front part, which undergoes such astonishing, unprecedented development in man, forms the cerebrum, or "great brain," which constitutes by far the greater part of the brain in man, and is its characteristic part. The first appearance and increasing development of this foremost swelling of the front end of the nervous tube, which is the physical counterpart of man's intelligence, can be traced from the earliest vertebrates to man.

The Skull's Accommodation for the Brain a Rough Measure of Mental Capacity

In humbler forms the cerebrum is a mere projection from a brain which mainly consists of the nervous centres of vision. Later it has grown, until it begins to turn backwards in order to find room, and thus hides part of the older brain from view.

This process continues until, in the highest animal brains, those of the anthropoid apes, the cerebrum hides the greater part of the rest of the brain, when looked at from above. But in man the cerebrum is enormous. The whole of the rest of the brain, with the spinal cord and the sympathetic nervous system thrown in, is dwarfed by it; and when we look at the brain from above we see nothing but cerebrum, all the older parts being hidden and well overlapped by it on all sides.

The great size of the brain is indicated by the great size of the skull or cranium of man. The peculiar development of the cranium is forwards, but it is no less notably developed sidewards and upwards, all to accommodate the mighty cerebrum of man. The study of the cranium, or craniology, thus assumes a special importance. The cranium varies widely in capacity in different individuals and races. Skulls can conveniently be filled with small-shot, and thus be estimated as regards capacity. Roughly, there *is* a correspondence between skull capacity and brain development, but the correspondence is so rough that we must ignore it, though its general significance, when we compare brains and crania, from the fishes upwards, is obvious. The attempt to find detailed correspondence between external cranial form and brain functions is, however, hopeless, for reasons already stated. There is, however, a new phrenology, as we shall see, which has something like the same relation to the old as chemistry to alchemy, or astronomy to astrology.

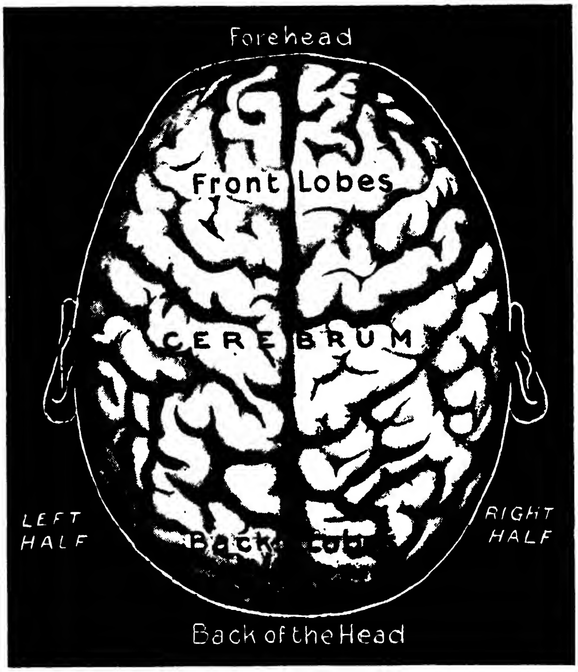
The Evolution of the Overlaid Cerebellum, or Little Brain

But first of all we must look at the lower parts of the brain, which are essential to life, and indispensable for the operations of the intelligence, though none of them is characteristic of man. Their study in anything like detail is inexhaustible, but the main facts are simple enough. First, we note that the brain, according to anatomists, ends at the level of the great hole in the base of the skull, where, if the brain ends, the spinal cord begins. The lowest part of the brain is, however, none other in structure than the uppermost part of the spinal cord, and since it is slightly larger it is known as the bulb, or *medulla oblongata*. Above this part we come to another, still continuous with it, which is called the *pons*, or bridge, for a very good reason. First, it communicates between the cerebrum and the bulb and spinal cord. Second, it communicates from side to side between the two halves of a very remarkable part of the brain, called the cerebellum.

The cerebellum, or little brain, is easily the largest part of the whole, after the cerebrum itself. It resembles the cerebrum in various particulars. For instance, it has two halves, with a communication between them. Its nerve-cells, or grey matter, are on the outside, and its nerve-fibres, or white matter, are on the inside. Its surface is broken up by very deep grooves, so that the surface is really much

larger than it would otherwise be, and so its grey matter is proportionately increased. In all these respects the cerebellum resembles the cerebrum, though the breaking up of its surface is much more simple and regular, so that it has a kind of series of leaves, as the pictures show.

The cerebellum also resembles the cerebrum in the very important respect that it is growing in the course of evolution. It is of unique size in man, but it has also been growing, like the cerebrum, along with the development of intelligence in the course of vertebrate evolution. It is really a very large organ in man, occupying an extensive part of the back of the skull; and there is no better testimony to the amazing development of the cerebrum than that it can completely cover this greatly developed cerebellum, as it does. We may foresee that there is a problem here.



THE BRAIN, SEEN FROM ABOVE

If the upper part of the skull of a man be removed, as in this picture, there would only be seen the cerebrum, or new brain, which has developed so greatly in man that it completely covers the cerebellum.

Packed together at the base of the brain, underneath the cerebrum, and therefore invisible until the brain is taken apart, we find some large masses of grey matter, which are called the basal ganglia of the brain. Their detailed names need not concern us. But we must now try to state the functions of the various parts of the brain that we have named, for there only remains the incomparable cerebrum itself, with which we must hereafter be almost exclusively concerned.

The medulla, or bulb, and the pons are simple enough as to function. Like the spinal cord, of which they are really the upper part, they contain a number of nerve-fibres or white matter, running up and down, and, in the case of the pons, also running across. But here we observe a unique and astonishing fact, which no one has yet begun to explain in any credible way. If we trace the nerve-fibres in this region, we find that a great strand of them, the greater number, in fact, cross over from each side of the body to the other. Why they should do so we cannot say, nor whether the fact may ever give us, perhaps, the key to the historical origin of the central nervous system of vertebrates. But there is the evident fact; and its consequences are no less evident, for it means that, in short, the right side of the cerebrum masters the left side of the body, and *vice versâ*. A vast range of facts of health and disease, and a great series of possibilities for surgery and for the localisation of maladies of the brain, depend upon this simple fact of the crossing over of the nerve-fibres from one side of the body to the other in this region.

But, like the spinal cord, the bulb and pons also contain within their substance a number of groups of nerve-cells, which are arranged in a series of pairs. These are the centres from which proceed a number of pairs of nerves, which have a variety of functions. These pairs of cranial nerves, as they are called, run to control the movements of the eyeballs, run to (or from) the ear, and the organs of balance, run to the muscles of expression, the tongue, and even to the heart and lungs and many of the organs in the abdomen. These last, the organs of the chest and abdomen, are all served by the eleventh pair, the last but one of cranial nerves, which are therefore called the *vagi*, or wandering nerves.

The details of the cranial nerves do not concern us here, but it does concern us that certain of these groups of nerve-cells club together, so to say, according to the destination of the nerves which run from them, so as to form "centres" for certain special

purposes of great importance. This is especially true of the bulb, where, as we already know, are found the centre that controls respiration—the so-called *punctum vitale,* or "vital point"—the various cardiac centres, the vaso-motor centre that controls the size of the blood-vessels, the centre for swallowing, a centre that somehow controls the proper utilisation of sugar in the body, and others besides.

The Oldest Part of the Brain the Part Least Easily Endangered

Obviously, therefore, though this is the smallest part of the brain, it is of great importance. It is the oldest part, containing the ancient centres for the control of the ancient functions discharged by organs as old as the heart and lungs. Its stability is great. All manner of poisons and degenerations, senile and other, will affect the later, higher, more delicate parts of the brain, according to the well-known rule of evolution, "last to come, first to go," but the bulb will remain. A man must be desperately drunk before his bulb is affected and his breathing is endangered, though that is the mode of death from acute alcoholism. Insanity or senility may have practically ruined the cerebrum, or, indeed, in idiocy the cerebrum may never even have developed, but the bulb will remain intact, maintaining the purely animal life, though there be nothing else to boast of. Hæmorrhage, also, into the bulb and pons is very rare—unless the base of the skull has been broken—and their blood-supply is very secure. The function of the cerebellum has long been highly obscure, and this organ has been deposed by modern science from the somewhat higher place which used to be given it. In the past, men located emotions of various kinds in the cerebellum, including love so-called, and hate. But we now know that the cerebellum has nothing to do with such things.

The Cerebellum the Organ of Balance and Mechanical Accuracy

It is, above all, the organ concerned with our control of the body, as regards its balance, its movements, and its muscular habits and aptitudes. If we recall the modern interpretation of the human brain as a whole, that it can learn any habit, make any machine, perform any action, construct *new* motor mechanisms, unlike the brain of any animal, we may realise why the cerebellum is so large in man, and may even realise that, notwithstanding all we have yet to say about the cerebrum, man would not be man even without his cerebellum. In its ordinary uses, this is the organ of balance. Thus a drunken gait is due to cerebellar poisoning, and such a gait in a sober person is the recognised sign of "cerebellar ataxia," which helps the neurologist to localise a tumour or other malady in that organ. But many other creatures have as much power of balance as man has, perhaps; and we must not suppose that this function is all or much of what the cerebellum achieves, though certainly this is the organ that the dancer, the skater, the cyclist, and the tight-rope walker must educate above all.

It is, we may suspect, the organ that forms new motor mechanisms within the body. When we learn not merely to walk, but also to write, and to talk, and to play the violin and the piano, and to sing, and to paint, and to sew, and perform surgical operations, and so forth—the list is endless, just because man is man—the cerebellum is being educated; and man has enough to his record for us to be assured that his cerebellum can learn anything.

The Unknown Functions of the Older Basal Part of the Brain

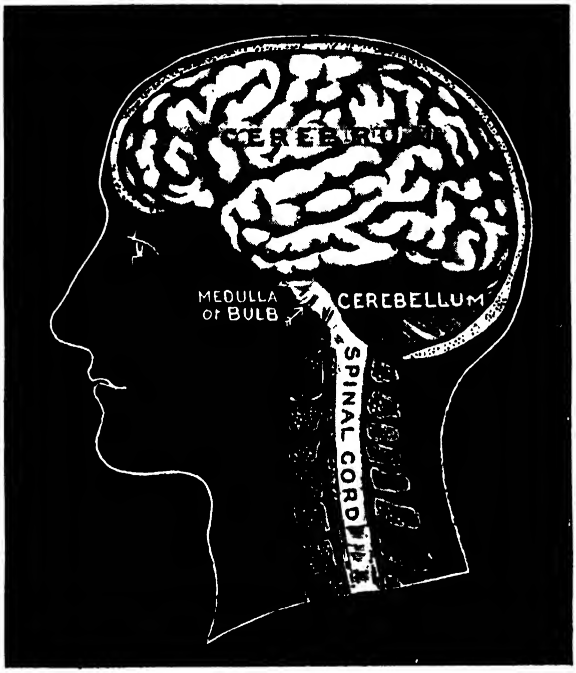
He can do what he was born to do; he can improve on this, and add dancing and skating to walking and running, by improving his capacities of balance. But he can do more. He can invent and construct absolutely new motor techniques, like those of the pianist or the surgeon, for his own special purposes; and thus we see why his incomparable cerebrum needs an incomparable cerebellum, and why their evolution has proceeded side by side since their first appearance in the world.

The uses of the basal ganglia are not very easily defined. They are very specially connected to nothing in particular, it would seem. Here is a great and complicated mass of nerve-cells, lying at the base of the brain on either side, which are not the obvious "centres" for anything. We do not find pairs of nerves emerging from them, as from the parts beneath them—the pons and the bulb. Nor do we find what the cerebellum shows so clearly—great numbers of nerve-fibres definitely proceeding from cells, and going to definite places. We find fibres from the cerebellum definitely running long distances in the spinal cord, for instance, and forming connections with both sides of the brain in all its parts. But the nerve cells which exist in such numbers in the basal ganglia do not send bundles of fibres to various parts in this fashion. They are not motor, like so much of the grey

matter we have seen already, from the spinal cord upwards, for no motor-nerves whatever spring from them. Neither are they directive and supervisory of motion, as the grey matter of the cerebellum has now been proved to be.

If they have nothing to do directly with the motor aspect of the nervous system, they must surely have something to do with its other aspect, which is that of sense or feeling. We examine, therefore, the various nerves of sensation to see whether they run to, and really spring from, the basal ganglia. The nerves of sensation are old structures in animal history, and so are the basal ganglia of the brain. We might well expect to find these ganglia the seat of sensation; and there is much reason to suppose that at one time they were. But it is one of the most remarkable and significant facts of the human brain that the centres of the various senses vision, touch, smell, and so on, which are exceedingly ancient, and existed in great power for untold ages before the evolution of the cerebrum at all are yet to be now found in the cerebrum—and nowhere else. These senses had centres when there was no cerebrum; they have centres now in animals that have no cerebrum, or or none worth mentioning. Our basal ganglia appear to correspond to such centres, but our senses have gone up higher. No doubt they still have intimate connections with the basal ganglia, and these ganglia may sometimes seem to be a sort of half-way house on the inward path of what will cause a sensation. But the reasoning centres are in the cerebrum; and if we want to know where a touch is felt, though the sense of touch is the oldest we possess, and is found in the amœba, and in every other animal, we learn that the centre for the sense of touch is upon the surface of the cerebrum, which is the very latest physical triumph of evolution.

The body has many instances of parts which appear to be useless, but nothing is less probable than that such parts should be found in the brain, occupying any of the priceless room within the skull. There remain two facts at least of the psychical life which we have not yet allocated to any part of the brain—the intelligence and the emotions. We should certainly not expect the intelligence, so recent and rare, to use the basal ganglia, so ancient and common, and least of all when we find that the sensations, which are the data of the intelligence, have left them. But the case of the emotions is very different. Of course, they require and will receive special study, none the less because the old psychology fell far short of doing them justice. But meanwhile we may reasonably state the very high probability that the seat of the emotions in the brain is the basal ganglia. They must have some seat in the central nervous system, and we can positively exclude all the lower parts of the brain and the spinal cord. We shall also be able to exclude the cerebrum as their seat —a fact of great importance. Only the basal ganglia remain, and there the emotions must find their seat, unless we are to accept the very taking and much-discussed theory of the late Professor William James, that the emotions have no real centre or origin in the brain at all, but are only the general effect of certain disturbances of our internal organs; that we feel afraid because we feel the heart palpitating, and not that the heart palpitates because we feel afraid, for instance. If we reject that theory, as we must while acknowledging some indebtednes



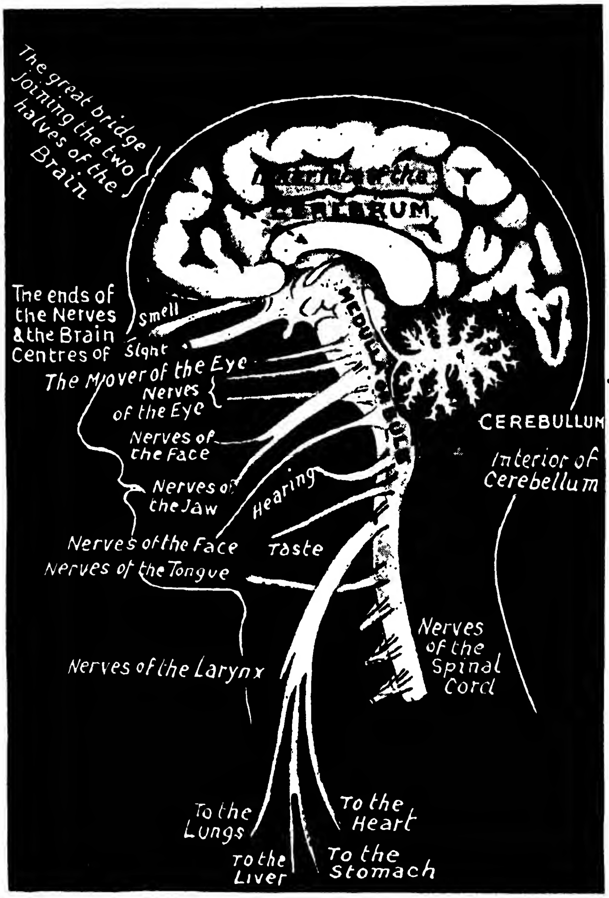
SIDE VIEW OF THE BRAIN

This picture shows how the brain lies in the skull and the relative positions of the much folded cerebrum, the cerebellum, the bulb, and the spinal cord.

to it, we cannot refuse to assign the basal ganglia of the brain to the emotions as their seat and centre.

The fuller meaning of this will be realised when we come to see the strict connection between the emotions and the instincts, only perceived by psychology during the present century. We may then incline to the view that these ancient ganglia of the brain are concerned with the organisation of the ancient instinctive responses of the living body, as well as with the emotions which accompany them; and we shall understand the close anatomical propinquity of the motor apparatus descending from the cerebrum to these great ganglia at the base of the brain.

Only the cerebrum and its functions remain for our study. But what an "only" is this! For the cerebrum of man is the indispensable instrument whereby he has built cities, written books, conquered the earth, and may even, at the last, become master of himself. The cerebrum is not a creator, but it is the infinite tool of man, the creator. To say that it alone remains for our study is to say that we have merely now to study man, his doings and his destiny! We shall not leave this subject; and here we must begin with a statement of the main anatomical facts.



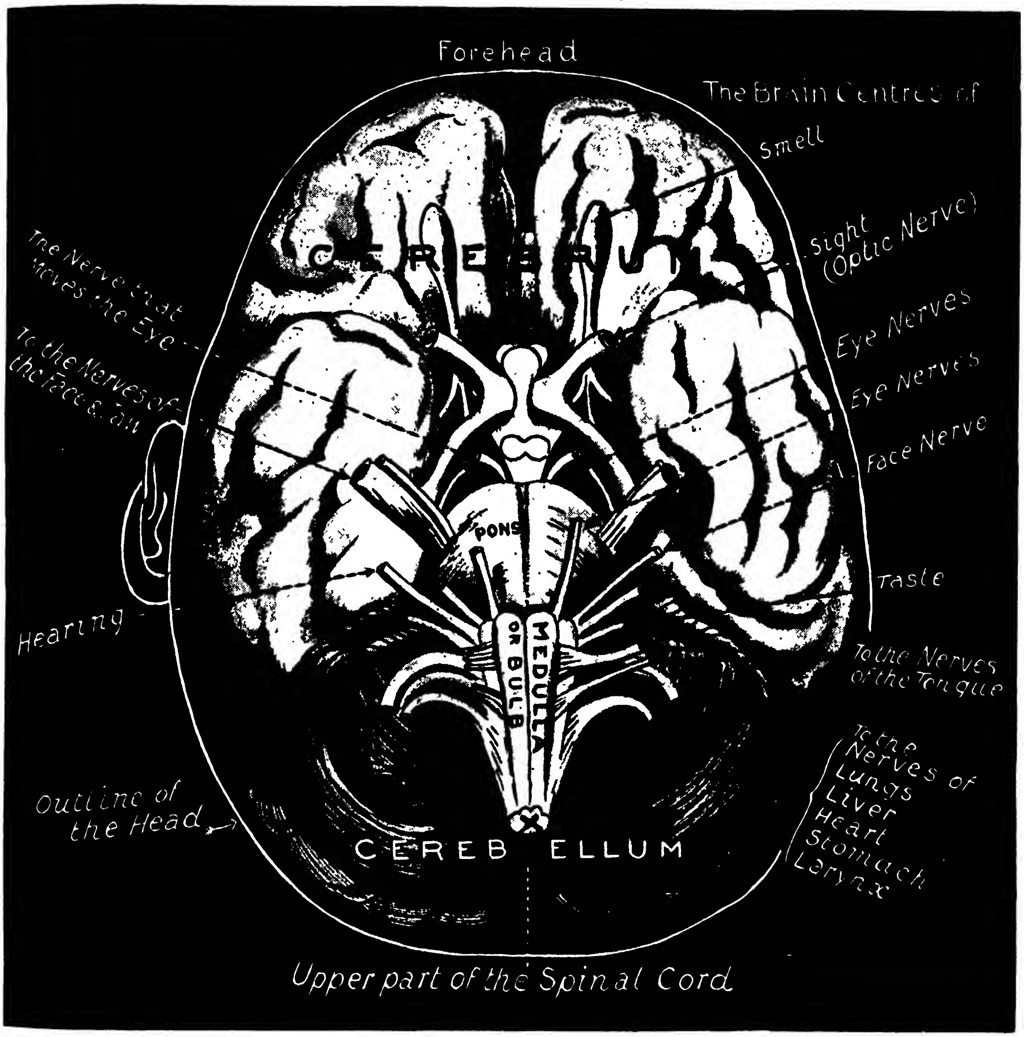
A SECTION THROUGH THE CENTRE OF THE BRAIN

In this picture-diagram of a section through brain and spinal cord are shown the roots of the cranial nerves and the order in which they leave the brain; one only of each pair is shown.

This cerebrum is a strictly double organ, consisting of two halves, one on each side, which are connected in various ways. We observed the legitimacy of regarding the heart as a double organ, and speaking of a left heart and a right heart. No less legitimate is it to speak, as we often do for short, of the left brain and the right brain. But the proper designation of these two halves, which we see at once in any but a side view of the brain, is the *cerebral hemispheres*—the two hemispheres of the brain wherewith man has conquered the two hemispheres of the earth. Ideally, so to say, they are symmetrical, but we find that, in the right-handed adult, the left hemisphere is always slightly the larger of the two, and conversely in left-handed persons. We shall find, also, that on critical examination of the functions of the hemispheres, this disparity is found to be far more marked, one or other being the "leading half" of the brain in everybody, and discharging exalted functions, such as speech, of which the other, the "led half," is incapable. But historically and ideally the two hemispheres are symmetrical; and this we observe directly we begin to follow the very strange and intricate pattern which they display upon their surface. They are not, however, independent. They can be brought into relation, somewhat indirectly, by means of messages sent down and up to and from the lower parts of the brain and spinal cord; they are connected by two tiny strands of nerve-fibres that cross the middle line, but chiefly they are connected by a very large and dense body of nerve-fibres, so firm that it is called the *corpus callosum*, which forms a myriad-fold bridge of communication

between the two sides of the cerebrum. We shall find that fibres from every part of both hemisphere, run through the corpus callosum from side to side, thus intimately connecting the two hemispheres and enabling them to act as one.

It is well known that we gain an advantage in seeing with both eyes. Binocular vision gives us a view a little way round an object, and we see its solidity and depth to some extent. Hence, Dr. John Brown, the famous author of "Rab and His Friends," argued long ago that there may be a difference between the kind of thinking that is performed with only one hemisphere and that which employs both sides, so that, as it were, we can think round and see round our subject better. This is at present only a suggestive speculation, and cannot be verified; nor need we necessarily assent to the view that reasoning is performed by interchange of messages between the two cerebral hemispheres by means of the corpus callosum. But it is at least certain, as we shall learn later, that the brain is very rich in association areas and association fibres, as they are called, which connect different parts of each hemisphere with each other; and the fibres which cross from one hemisphere to the other are evidently part of the general association system that is found to be so marked a



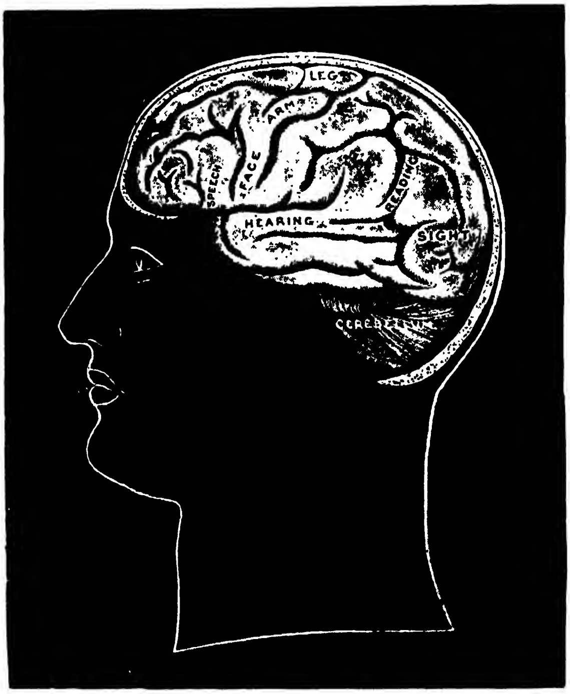
PICTURE-DIAGRAM OF THE BRAIN AS SEEN FROM BENEATH

The entire nerve of smell and the nerve-roots of the other senses and the vital organs are shown in this picture. These nerves are arranged in pairs, two for each sense, and are drawn in the order in which they are attached to the cerebrum, pons, and bulb. The crossing of the optic nerves can be clearly seen.

characteristic of the human brain. And unless we assume, as some have done, that the "leading half" of the brain does all the thinking and all the remembering, which is highly improbable, we must agree that congenital absence of the corpus callosum, as is found in some defective brains, must sadly interfere with thought, and that it is well to try to use both sides of the brain, rather than one only. But whether this is to be achieved by the cultivation of ambidexterity, and whether it is impossible except for those who have learnt to write, and so on, with both hands, is another question which we shall not attempt to decide at present. But we see the anatomical basis for the theory of the champions of ambidexterity.

The cerebral hemispheres are covered with a triple coat of membranes, or meninges, inflammation in which, due to the microbe of tuberculosis, or another, constitutes the well-known malady called meningitis. If this occurs very early in development, and interferes with the circulation of fluid inside the central canal of the nervous system, as it may do by blocking up certain apertures, the fluid increases in bulk, and swells the brain and the head, producing hydrocephalus, or water on the brain. But though we must recognise the existence of the central canal of the nervous system, and of the "cerebro-spinal fluid" which it contains, and of the ciliated cells which line the tube, we are still uncertain as to the functions of this fluid, and the spaces, within the cerebral hemispheres, which it fills.

Under the three meninges, or "mothers," of the brain, the *dura mater*, the *arachnoid mater*, and the *pia mater*—"hard," "spider-like," and "pious," respectively, in the old terminology—we come to the surface of the hemispheres themselves; and a glance within shows that the disposition of the nervous elements is the same here as in the cerebellum, and the opposite of what we find, for instance, in the spinal cord. The grey matter, containing the nerve-cells, is without, and the white matter, composed of the nerve-fibres, is within. We see, further, a similar arrangement for increasing the surface to that which was employed in the cerebellum. The surface of the hemispheres is deeply grooved with a great complication of branching fissures, or *sulci*, which mark the surface out into a number of folds, convolutions, or *gyri*. The grey matter dips down into the fissures, thereby explaining their presence. If the grey matter of the average brain were to be disposed in its present thickness, upon a smooth surface, the brain, and therefore the skull, would have to be most unmanageably large. The brain has steadily grown. The earliest cerebrum we know, far down in the scale of life, is perfectly smooth. Gradually the device of infolding has been adopted, to afford a larger surface in the same space. We pass upwards through the vertebrate series, and find the head, the cerebrum, and the folds of the cerebrum steadily increasing. The growth of the cerebral *surface* has constantly outrun the growth of its bulk and of the skull. Thus, the fissures are always becoming deeper and more numerous, until we reach the cerebrum of man, in which the hemispheres are fissured to an unparalleled degree, both in number and in depth. We may argue that the grey matter might have been made thicker, and it is thicker than it used to be, but evidently there is a limit to useful

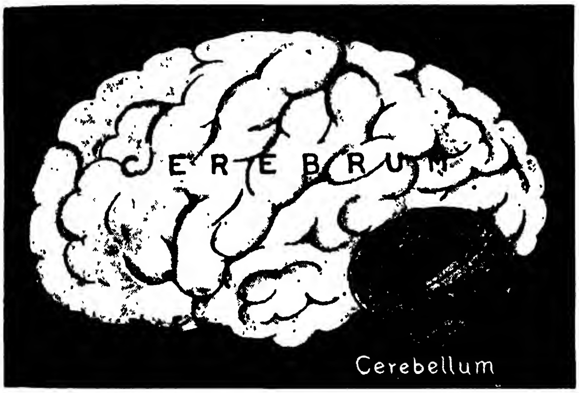


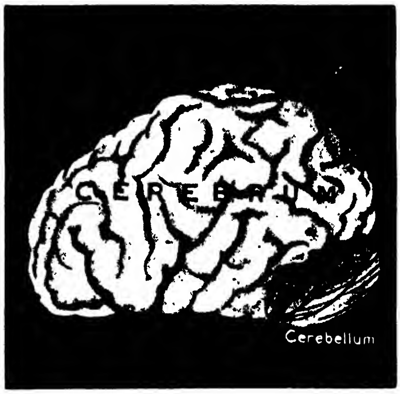
SOME CONTROL-CENTRES OF THE BRAIN
This picture-diagram of the left surface of the brain shows the portions concerned with various senses and movements of limbs. Should the portion of the brain marked "leg" be destroyed, paralysis of the right leg would result.

thickness, and intercommunicating areas of wide extent are preferred. That is attained by thus throwing the surface of the brain into a series of convolutions.

The number and depth of the convolutions vary very considerably in different people, and are undoubtedly related to the quality of the brain, to which they afford a far more trustworthy index than its mere bulk. This fact is, of course, fatal to the pretensions of "phrenology," while it offers the possibility of a new phrenology to which there may be no end. The *extent of surface* gives us, substantially, the *real size* of the brain. Just as comparative and evolutionary study suggests, the fissures are most numerous and deepest in the brains of the higher races, and in individuals of the highest cerebral powers. And agencies, toxic and other, which practically reduce the extent of the brain surface, by destroying the cells which compose it, do directly reduce the mental capacities, as also often the moral capacities, of the affected individual.

The white core of a cerebral hemisphere constitutes by far the greater part of its bulk. The fibres run in all directions, and must be traced, to some extent, when we try to unravel the working of the brain. Meanwhile, we reflect that, for every one of these fibres, there must somewhere be a nerve-cell which nourishes it and employs it, and from which it sprang. The nerve-cells, then, are the essential part of the hemisphere, and we find them exclusively in the grey matter of the surface. In the white core none are to be found. Other cells there are: those which constitute the walls of blood-vessels and lymph-vessels, and also a peculiar type of cell, with many branching processes, which are called *neuroglia*, or "nerve-glue," cells. They are the connective tissue, the "glue," of this part of the body, and are peculiar to it. Everywhere they fill in gaps and hold things together. They look very unlike ordinary connective tissue-cells, and rather like nerve-cells, as if apeing the tissue they serve. But they are only humble connective tissue-cells, nevertheless, formed from the mesoblast, or middle layer, of the embryo, and they retain the primitive power of division and multiplication which nerve-cells have utterly lost. Thus, when nerve-cells are destroyed, by poisons or otherwise, neuroglia-cells take their place; and the degenerate brain, perhaps bigger than ever, consists of connective tissue which cannot think, just as the degenerate heart, also larger than ever, consists of connective tissue which cannot contract. Further, we observe that the various tumours of the brain never consist of nerve-cells, which are incapable of forming tumours, innocent or malignant, but consist of cells derived from the neuroglia or the meninges, or some other humble tissue.





THE SIZE AND STRUCTURE OF THE BRAIN OF MAN AND GORILLA COMPARED

The brain of the gorilla is about two-thirds the length and between two-fifths and one-third the bulk of the human brain. Its frontal lobes are low and poorly developed, and the cerebrum does not extend beyond the cerebellum.

And so we pass to the last anatomical unit of the cerebrum, the nerve-cell, as we find it in its millions in the mantle of grey matter that covers the hemispheres and lines their fissures. If we make a section through a hemisphere, at any point, the contrast between the grey surface and the white interior is very obvious. The grey matter is the "bark of the cerebrum," or *cortex cerebri*. It is the essential home of man, his organ of organs, instrument of instruments, becoming more and more the master of all the nerve-cells beneath it, and through them of the external world.

LONDON'S BID FOR HEALTH FROM PLAY

CRICKET AT ST. QUINTIN PARK, IN THE WEST OF LONDON

THE PLAYING FIELDS AT CROUCH END, A NORTHERN SUBURB OF LONDON

ON THE FRINGE OF LONDON—CRICKET AT MOTTINGHAM, NEAR ELTHAM

The photographs on these pages are by courtesy of the London Playing Fields Association and Gordon Smith

RIGHT KINDS OF EXERCISE

The Supreme Importance of Where Exercise is Taken, and of Action Without Strain

WHY PLAY IN THE OPEN AIR IS IDEAL

If we hold fast by the principles of the New Asceticism, and if we also remember the dangers of excess in exercise, as in everything else, we may now make speedy and certain decisions as to the right kinds of exercise for ourselves at any age, and for everyone else. We shall exercise not for the development of large muscles and the consequent attainment of strength; nor yet in order to avert the consequences of over-eating, which are best treated by "removing the cause," but for the health, and healthy stimulation, of the brain, and of whatever serves the brain.

We may begin with a form of exercise at which many of us must have laughed in our time. It is what is called "carriage-exercise," and we place it first here, because it illustrates the new view of exercise as nothing else can, unnatural in a sense though it be. We are wrong in thinking that the term "carriage-exercise" is an absurdity, invented by too prosperous people and their obliging doctors as an excuse for laziness. It often is an excuse for laziness; and the peculiar type of bored and vacuous faces, at once fat and flabby, which we see so often in "carriage-folk," though less so nowadays, thanks to the motor-car, is undoubtedly the outward and visible sign of an inward laziness and indulgence that need something far more vigorous than "carriage-exercise" to correct them. The motor-car moves so much more rapidly that motor-exercise, as it might be called, really comes much nearer to riding-exercise, both as regards the influence upon the skin and influence upon the muscles concerned in maintaining the body upright.

Carriage-exercise of all grades, from a seat on the front of a four-horse coach to a seat in a bath-chair, is now known to be valuable on account, above all, of its action upon the skin. The reader who remembers our chapters on air and ventilation, and especially that upon the difference between "fresh air" and "open air," is fully prepared for the present argument—which, by the way, has also been endorsed by the very high authority of Sir Edwin Ray Lankester since its acceptance in this work. To the gymnast or the cricketer, no doubt, it seems monstrous to apply such a word as "exercise" to mere exposure to moving air, for he means by exercise something that stretches the muscles. But it has now been proved that even carriage-exercise, however lazy it appears, does actually stretch the muscles by a reflex action exerted through the nerves of the skin. No doubt this exercise is hopelessly inadequate for the great majority of those who can afford it; but if anyone doubts whether this kind of thing can really be exercise, let him undertake a first ride in a bath-chair "along the front," after influenza or appendicitis, and have his ride just five minutes too long. He will very quickly learn that though in health we live merely upon the very margin of our physiological income, and have enormous funds to spare, so that the expenditure involved in carriage-exercise is unnoticeable, yet it may be a very heavy tax indeed when illness has ravaged our resources and the physiological funds are low.

The truth is that the recent experiments, made in the laboratory, on the action of moving air upon the skin, and thence by reflex action upon the muscles, the glands, the production of heat, and the processes of secretion, have given all students new ideas of the importance of the skin and of cutaneous stimulation. They have shown that the most expensive and elaborate systems of ventilation, such as that employed for the House of Commons, which

produces a perfectly pure and motionless atmosphere, are the worst that can be devised. In such a "dead air," as it has well been named, our skins lose an indispensable necessity for real health, during every moment except when we are asleep—namely, the stimulation of tiny, incessant blows, striking us in all directions, and dealt us by little currents of air. We say that a man wants a pin run into him to wake him up. Just so does the nervous system require the incessant tiny pricks of shafts of air if it is to work properly. Here, at last, it need hardly be said, is the kindest explanation of the House of Commons, though its adequacy may still be doubted.

All this means that the various forms of exercise which consist, apparently, of no more than passive and effortless exposure to moving air—whether it moves past us, or we move through it, is, of course, immaterial—are being rehabilitated in the estimation of hygienists. We now understand what the practising doctors see every day, and have always believed in, though they could give no adequate explanation of it—that nothing brings ill people back to health, nothing hastens convalescence, nothing rouses the protective forces of the body, say in consumption, better than, or even so well as, exposure to moving air.

The Perfect and Peerless Exercise of Swimming in Moving Water

The degree of motion and the degree of exposure must be regulated, of course, but the principle remains for everyone, from the child to the centenarian, both in health and in illness. These considerations, to which every month of inquiry lends force, justify our view already stated—that it is not really worth while to grow enthusiastic about systems of ventilation, or to discuss them in detail, however much the reader may desire it. When physiology has reached the conclusion that the extremely expensive and elaborate and "perfect" system of ventilation employed in, say, the House of Commons is the very worst, because the most unnatural and most deadly that can be devised, the hygienist has no choice but to leave all these methods on one side and sing the praises of the open air, for it becomes obvious that "none but itself can be its parallel."

We carefully note that the peculiar and inimitable advantages of the open air are due not to its composition but to its motion. This is the justification for what many may have thought to be our extravagant praise of swimming in the open air as an exercise. We said that there was nothing like it, and now we see that there cannot be. Just what moving air does to the skin, moving water does also, only still more efficiently; and if we swim under the sky, perhaps especially in the surf, we have a form of exercise which, physiologically judged, can only be called perfect and peerless. Of this we remind ourselves, and then we shall be prepared for what is to follow—the condemnation of many forms of exercise now greatly admired and enjoying an unexampled vogue.

The High Value of Air-Stimulation Applied to the Skin, with Exercise

Now and henceforth we are compelled to appraise different forms of exercise, first of all *not* in terms of foot-pounds of energy concerned, or particular muscles employed and enlarged, or even particular modes of breathing encouraged, or the massage of the liver, but in terms of the kind and degree of stimulation applied to the skin. We shall see that the mere undressing associated with many forms of exercise has a value, perhaps more value than anything else. The best thing about many forms of exercise may be that they enable us to undress and expose our skins to the air without catching cold! The swimmer who offers most of his skin-surface to wind and water, the runner who wears "shorts" and socks, even the cricketer who, at least, rolls up his sleeves and bares his throat—all of these are already obeying the laws of health, quite apart from what they proceed to do next. But what they do next is to move about, which means more stimulation of the exposed skin, and means production of heat, so that they do not catch cold.

The Utter Wrongness of Incubation by Central-Heating as in the House of Commons

Let us now consider the gymnasium or play-room, for badminton or what not, of some modern hotel or hydropathic, with "chauffage centrale," or "central heating throughout," as the advertisements are careful to remind us. At once we see that, in providing for exercise, the first conditions of really good exercise have been purposely and systematically excluded. It is all wrong. Except for a prematurely born infant in its incubator, or for the incubating eggs of some bird, the whole theory of "chauffage centrale," or hot-water pipes in general, is wrong—not merely for exercise but at all times. Not merely House of Commons debates, but many sermons, we begin to see, are thus in part explained and

excused. More than that, we begin to understand the many cases where the pale and tired shopgirl, for instance, who has worked in a centrally heated shop all day, and whom we had sent to a centrally heated gymnasium for recreation and exhilaration in the evening, derives no profit from our care and the charity of our friends, from whom we have begged for her.

In short, exercise elsewhere than in the open air is condemned. It may often be better than nothing, if only that, say, gymnastic dress gives the skin a chance of stimulation, at least as regards the neck and arms, but even this and the movement in the gymnasium are practically useless if there has been nothing but a still, dead, warm air to move through. Again, the reader will observe, we are forced back to Nature; as usual, we have been too clever by half. In our schools, architecture, sanitation, and ventilation have done their best, ever improving upon themselves; and we have learnt that their best is their worst. At the very moment when they have said their last word, we escape from them altogether, and start open-air schools, first for ailing and then by a daring inference! —for healthy children.

A New Period of Invention and Design Opening for Architects

It will be just so with exercise. If algebra and ancient history are best taught in the open air, one scarcely sees the children being taken indoors for only one lesson in the day, and that the gymnastic lesson. The fact is that the closed gymnasium, be it heated never so centrally, is doomed. All our provision for exercise in the future, whether for ourselves or for children, must be made in the open air. The architects will by no means be superseded. On the contrary, a new period of invention and design opens before them. The splendid new open-air school just outside Birmingham illustrates the possibilities and the nature of the new demand. Architects must give us good floors, roofs of a sort, and walls of a sort, that can be moved or abolished at a moment's notice, and with all this they must give us something beautiful, easily flooded with sunlight, and yet able to exclude it when necessary! Such requirements sound impracticable, but they are actually being met to-day.

With the closed gymnasium, at least as it is usually to be found, there go into the limbo of the past all those forms and devices of exercise which are to be practised in one's bedroom and similar places. From beginning to end, their assumptions are all wrong. The object of exercise is not large muscles; contraction of muscles does not achieve the other objects of exercise, even if we admit them; and there is no spectacle more absurd than that of the well-meaning searcher after health, who might be tasting the winds of the morning, and growing towards its light, but who is, instead, to be found, strapped or hanged by some device of rubber and metal, to the back of his bedroom door, closed as the windows are, and breathing the still mixture of poisons which he has been pouring into the air all night.

Supineness in the Open Air Better Than Exercise in an Indoor Gymnasium

Such a misguided individual probably requires a chart of exercises, showing him what contortions to assume for the development of his trapezius, his latissimus dorsi, his deltoid and his biceps, but he will look long before he finds a page of POPULAR SCIENCE wasted on such nonsense.

Undoubtedly one of the valuable results of exercise is its promotion of full breathing, but deep breathing can really be of very little value unless it be the breathing of pure air. Indeed, if one had to choose between exercise in the ordinary indoor atmosphere and lying supine in the open air, it would be wise to choose the latter. Every indoor gymnasium, every system of developers and exercisers, is to be condemned if it keeps people indoors. There is no comparison, on the score of health, between the most elaborate and carefully thought-out system of indoor exercise, however complicated the apparatus and certificated the teachers, and the most informal stroll or scamper out of doors.

The Folly of Development of Muscles by Means of Indoor Exercises

In all large cities nowadays there are to be found people of both sexes who devote some portion of the day to exercise—not because they particularly enjoy it, but for the sake of health. To this end, they go indoors when they might be out of doors. Boys and young men are encouraged to measure their progress and profit by the size of their muscles, and the teachers publish photographs showing the marvellous development of the muscles of the shoulder-girdle or the upper arm under this or that system. But nothing at all has been accomplished when these muscles have been developed to their maximum size. Much less than nothing has been accomplished if their owner, while developing

them, has been breathing the ordinary air of an indoor apartment when he might have been out of doors.

Anyone who will consider for a moment the natural constitution of man, and the principles of natural education, must agree that the deplorable thing called a dumb-bell offers an exquisite parody of what exercise should really be. The cat—as she exercises her kittens, along the lines of their natural proclivities and needs, never telling them that this is exercise for the sake of exercise, and certainly prepared, if she could, to turn up her nose at any artificial implement we might offer her—should be our model in this respect.

All Exercise for the Sake of Exercise a Second-Best Method

It may be imagined that some unfortunate girl, brought up on Early Victorian lines, having never been permitted to wear comfortable garments or to stretch her arms, would welcome the use of dumb-bells when first introduced to them. But anyone who has had a natural childhood, who has been taught to play, and who has taken his or her exercise naturally in the course of pursuing some mental interest—any such person may be excused for thinking that a pair of dumb-bells should be deposited in our museums as indications of what was understood by exercise even as late as the earlier years of the twentieth century.

All exercise for the sake of exercise is a mistake—or, at any rate, a second-best. You may do your mind, and body too, more harm by sheer boredom than you may gain good from the exercise you go through. The dumb-bell is misnamed, for it shouts aloud the fact that the most elementary and obvious truths of psychology are still unrecognised, though the play and games of every natural child—if you object to being instructed by kittens—should be quite enough to teach us what, indeed, Nature taught us ages ago, if only we would listen to her.

The Value of a Purpose Beyond Exercise While Taking Exercise

Everyone knows the difference it makes to have "an object" when one goes for a walk; and this universal and natural fact teaches us that we are not meant or constructed to take exercise for itself, but only to take it incidentally, without thinking about it, on the way to some end. The cricketer who saves a boundary benefits by the running, just because he is not running for running's sake, but in order to reach a ball and help his side to win. Hence, in games, when no other object is available we have to make winning an object, and then the incidental exercise is cheerfully undertaken and becomes valuable. Doctors in the recent past have often been very hard on their consumptive patients, wanting them to be in the open air, and sending them on objectless and uncompanioned walks, which simply dispirited and weakened instead of helping them. And in the new methods of therapeutic exercise for consumption, which are now coming into vogue at all sanatoria, and which must be discussed elsewhere in this work—based as they are upon the doctrine of acquired immunity to the toxins of the tubercle bacillus—the rule is to give the patients a piece of constructive work to do, with an end to aim at, and the fruit of their labours visible in front of them.

Exactly the same argument, for it is indeed of universal application, is illustrated by the contrast between the useful and interesting work to which our young convicts are now set under the Borstal system, and the brutal stupidity of the treadmill and oakum-picking in the past. We shall really learn in time that man is primarily a mind, made for purposes.

Happiness the Most Powerful of Tonics While Taking Recreation

There is no help for it—we must quote Herbert Spencer. That is the worst of a really great thinker: there is no getting away from him. All that we now argue on physiological grounds and psychological grounds, most of which have only been established quite lately, was proclaimed by Spencer more than half a century ago. In five months he had never heard a shout or a laugh proceed from a girls' school only a few yards distant from his house. Once in that period he saw a girl chase another round the garden. On the popular view of Spencer as a dry and bloodless philosopher, he might have been expected to be grateful for the quiet. It disgusted him. And then he goes on to say that "The natural spontaneous exercise having been forbidden, and the bad consequences of no exercise having become conspicuous, there has been adopted a system of factitious exercise—gymnastics. That this is better than nothing, we admit; but that it is an adequate substitute for play, we deny . . . The common assumption that, so long as the amount of bodily action is the same, it matters not whether it be pleasurable or otherwise, is a grave mistake. . . . The truth is that happiness is the most powerful

of tonics. . . . Hence the intrinsic superiority of play to gymnastics. The extreme interest felt by children in their games, and the riotous glee with which they carry on their rougher frolics, are of as much importance as the accompanying exertion. And as not supplying these mental stimuli, gymnastics must be radically defective.

"Granting, then, as we do, that formal exercises of the limbs are better than nothing—granting, further, that they may be used with advantage as supplementary aids—we yet contend that they can never serve in place of the exercises prompted by nature. For girls, as well as boys, the sportive activities to which the instincts impel are essential to bodily welfare. Whoever forbids them, forbids the divinely appointed means to physical development."

That last is a fine sentence, daring in its day, but acknowledged now. We begin to be able to state the case for various exercises. Walking, no doubt, is pre-eminent in safety and convenience, but we must qualify our statement. Walking in foul, still air does not produce the good effects of exercise. This is the condemnation of the walking round a billiard-table as exercise, though it can easily be shown that the player must walk miles in the course of an evening, and exercise many other muscles besides.

The Inadequacy of Walks that Are Taken Merely as Constitutionals

The first need of exercise is not met in the foul, dead air. Secondly, walking in the open air is an inadequate exercise in itself for those whom it bores. If they have something to look at or to get, or any kind of purpose, or a dear companion, all is well, but doctors are abandoning the indiscriminate ordering of mere "constitutionals" as such; they know more about the human constitution now. Walking is an inadequate exercise, in itself, for the reduction of weight in cases of obesity; and many walkers for their figures' sake have been disappointed in this respect. The great hygienic virtue of the form of exercise called golf, described as a game by many, is that they find it a game; and just because they have an object, they undertake the walking first, and the exposure to the open air second, which do them so much good.

The truth is that the best exercise, other things being equal, is that which we most enjoy, for happiness is the best tonic. Thus, though it is possible to generalise about the best exercise on the assumption that man is a machine, on any other assumption we must find out in the individual case what is enjoyed. But the enjoyment must be natural, and compatible with open air. Also, we must condemn all forms of exercise, whether or not the individual happens to enjoy them, which interfere with breathing. This entirely condemns weight-lifting, and some other forms of crude gymnastics. To interfere with breathing is bad in itself, and it is bad for the heart, which largely depends for its health and its proper functioning upon the help it derives from the movement of the lungs.

The Badness and Danger of All Games That Involve Great Strain

On similar grounds, those exercises are bad in which you are stimulated to put in "the last ounce;" and here, again, is an argument in favour of games, as against even such comparatively natural forms of exercise as running races. You may play a game for all you are worth, but, if it is worth calling a game at all, this does not involve putting in "the last ounce." On the contrary, if you "press" at golf you "foozle," and if you bowl your hardest at cricket you give runs away. But in running races the purely physical element is uppermost; and if other kinds of races are to be questioned, especially for the young, swimming races are notably to be criticised, on account of the very great exertion involved under conditions which are not exactly natural, however excellent within limits.

Our condemnation of weight-lifting and the like, on the ground of their interference with breathing, applies also to short races. Runners are taught not to breathe at all during, say, a hundred yards sprint. The lungs are inflated, fixed, and only deflated when the race is over. This undoubtedly makes for speed, but it is exceedingly bad for the heart.

The Viciousness of Artificial Aids Towards Extreme Physical Endurance

The latest device is the inhalation of oxygen gas from a cylinder before the race, so that the expert may hope to be able to run even a quarter of a mile without deflating the chest, say in fifty seconds or less. All this is entirely vicious, and must be condemned without reserve. These are the kinds of practices which result in permanent dilatation of the heart, stretching and bursting of the ultimate air-cells in the lungs, and the allied evils which have led to the round condemnation of all competitive sports by the American Commission on the subject.

Obviously, cycling cannot be reckoned a perfect exercise, but there is no real objection to it as a means to the ends of companionship or seeing the country, and it is often very useful indeed in constipation. Special remedial exercises for constipation may also be employed with success. Thus the subject of constipation will do well to perform such amusements as twisting his trunk round in either direction without moving his feet, lying on the ground and raising the head and trunk, and also the deliberate indrawing of the abdomen by direct contraction of the abdominal muscles. This effects a very thorough massage and stimulation of the stomach and bowel, and is better than artificial massage by means of the hand, or by rolling a cannon-ball over the abdomen, and so on. This exercise is more effective, more even and more natural. Doubtless it is less trouble to swallow a pill, but abdominal exercise is far better. Best of all are attention to the diet, and exercises in the open air, active and interesting, which will cure the constipation indirectly.

Breathing exercise is another form of special exercise which, though taken for its own sake, has something to be said for it. The singer has the great advantage of taking breathing exercise incidentally, and not for its own sake. The cases are familiar where the prescription of singing has brought health to weary and ailing people; but though the effect upon the movements of breathing is usually credited in such cases, some therapeutic virtue must assuredly attach to the music and to the pleasure of self-expression. But singers, as a whole, should cultivate more love of the fresh and open air. The present writer, as a boy, once had the good fortune to ride in a cab with Madame Antoinette Sterling to a concert, and will never forget her amused disgust at his suggestion that the windows should be shut in the interests of her voice. Many other singers might learn from her.

Many people who do not sing may profit by taking breathing exercises. But the air breathed must be fresh. Five minutes of deliberate deep breathing at the open window is not a bad discipline for the beginning of the day. It involves practising the elasticity of all parts of the lungs, and preventing stagnation of the blood in them. By means of the diaphragm it involves a rhythmical squeezing of the liver almost as a hand squeezes a sponge. This makes for health and digestion, and opposes constipation. Deep breathing has unfortunately become too often the prey of cranks, and we must beware of making absurd and universal claims for it—above all, when we consider the importance of breathing the right thing and the consequences of breathing foul and infected air, be it never so deeply. Still, it is certain that exercises which interfere with free breathing are bad; and we may say that, on the whole, other exercises are good largely in proportion as they favour free breathing, with its beneficial action upon the organs of the abdomen, and also upon the heart itself.

THE INVIGORATING SURF—AUSTRALIANS BATHING IN AIR AND SEA

Modern therapeutic methods very largely include the use of massage; and though it may seem that massage is not an exercise, we must briefly note it here, and observe that it has some of the characteristics of exercise. Properly applied massage, combined with passive movements of the joints—that is, movements made by the masseur—may be invaluable in many forms of illness. Joints are meant to move; and therefore, according to a universal law of life, if they be not moved they stiffen. In cases of fracture, or confinement to bed for any reason, massage and passive movements are often invaluable in preserving the health of the joints; and the average stay of patients in

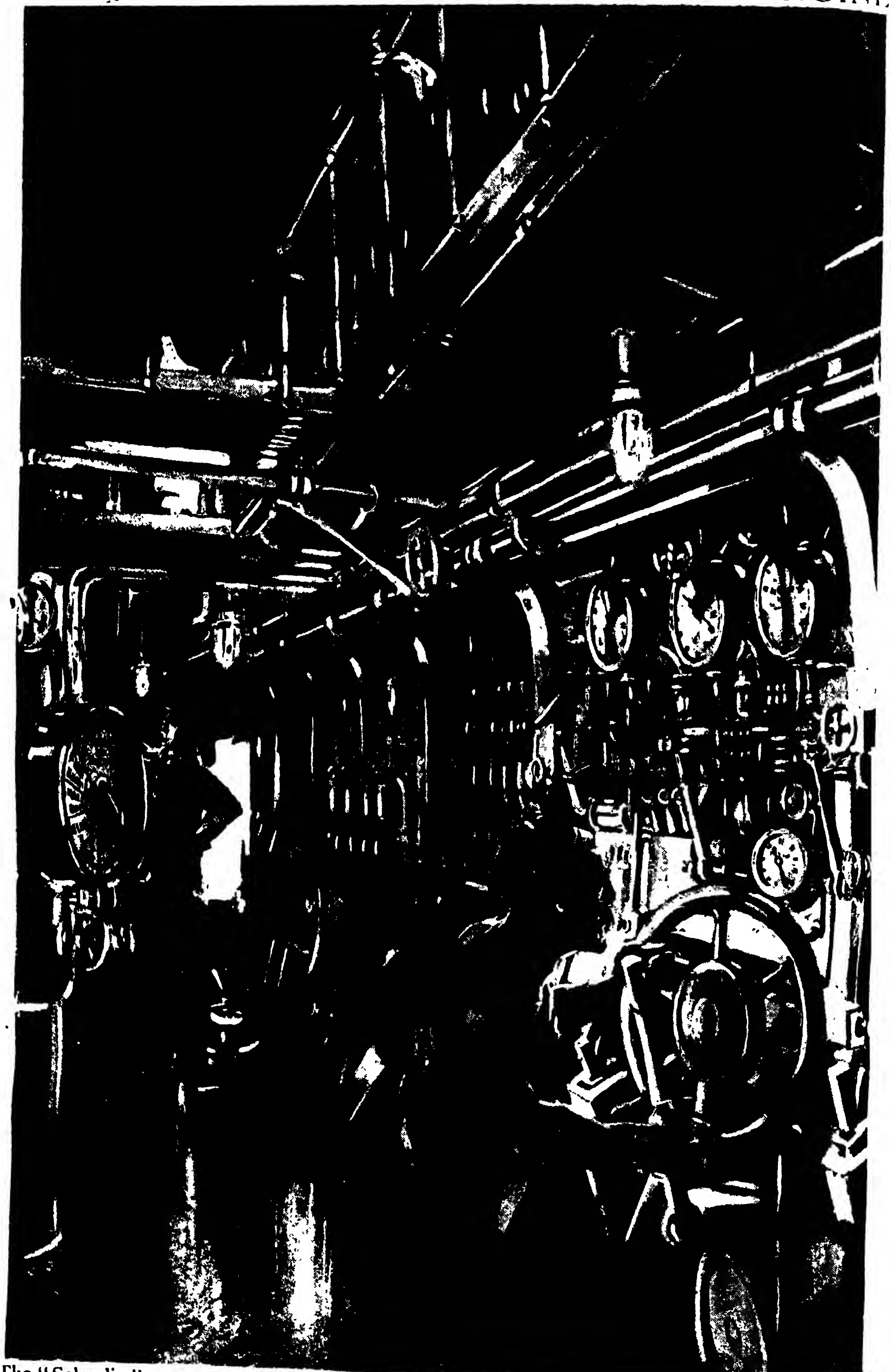
bed, under various disease-headings, has been much shortened in recent times by the full appreciation of the place of massage and passive movements in therapeutics. Further, there are many kinds of illness, such as nervous exhaustion, sleeplessness, paralysis, and so forth, where the ordinary employment of exercise is out of the question, because the nerve-cells which normally order the muscles are tired, and require rest. Yet there is nothing the matter with the muscles themselves, nor with the joints; and if the nerves are to rest, the muscles and joints will certainly suffer from having rest enforced on them. Here massage and passive movements come to the rescue. The muscles and joints are stretched and bent from without, while the patient's tired nerve-cells continue to rest, and the massage keeps going the circulation of lymph through the muscles, almost as well as if they were being squeezed by their own normal contractions. These are the kinds of methods, with the reasoning that underlies them, which are so largely replacing drugs and stimulants in the modern treatment of disease.

But in health, for young and middle-aged and elderly, there is nothing like play. That is the verdict of modern physiology and psychology alike. Health and joy come from the attainment of skill, not of strength; skill, which is man's characteristic, rather than the animal strength which his skill has superseded and masters. "The play's the thing," if we may adapt Hamlet—open-air play, with its interest, with *withdrawal of the mind from the cares of life,* which is worth more than all its other virtues put together. In games we exercise not merely the muscles, but the senses; they are therefore educational for young people, in the profound sense, as other forms of "physical education," so-called, are not. And the value of a purposeful movement made in a game is of a wholly different order from that of a not dissimilar movement which may exercise just the same muscles, for it involves the training of the neuro-muscular apparatus as an instrument of the will.

However heartily most cricketers or tennis-players may despise golf, the popularity of that game has been and is of the greatest service to elderly men, who have had little else than bowls so far. Every period of life is now well provided for in the matter of games, and only the very old need abandon them. They must be played in reason, and with adaptation to age and to sex. Cricket is supreme for men and boys. Tennis has high recommendations for both sexes, and for a very wide range of age. Hockey has a high place. Football is a much lower type of game, judged by the ratio of strength to skill which we have implicitly accepted as the human criterion. Much might be said as to the moral education, in discipline, self-control, judgment, unselfishness, honesty, and so on, that are required in the finest playing of the finest games, but this will suffice. There are worse mottoes, for hygiene and for work, for life and for death, than "To play the game."

PLAYING HOCKEY, THE GAME THAT GIVES HEALTH TO THE TWENTIETH CENTURY GIRL

THE SELANDIA'S STARBOARD MOTOR-ENGINE



The "Selandia," a 7400-ton vessel, of Copenhagen, with engines of 2500 horse-power, uses only oil-fuel.
1914

AN ENGINE OF REVOLUTION

Motor-Ships Ousting Steamers from the Seas and Reviving the Wind-Jammer

HOW DR. DIESEL IS CHANGING THE WORLD

EXTRAORDINARY is the speed of mind with which the resources of civilisation are now being developed. We are living in a whirl of revolutionary forces compared with which all the political revolutions that have happened seem insignificant. An old writer used to say he did not care who made the laws of the people so long as he created some of their songs. He meant, of course, that a man of genius who moulds the mind of a nation has more actual influence over its destinies than the legislators who merely record in new laws the changes in the mental atmosphere they have helped to produce. Knox, for instance, did more to shape modern Scotland than any king or minister; and Robert Burns afterwards undermined the influence of Knox as the most powerful House of Parliament could not have done.

A small band of men with a high force of creative imagination still controls the destinies of the human race. Some of them work by word and example on the minds of their fellow-men, creating a new temper of intellect, a new complexion of ideas and emotions that change the spirit of the age and give it a fresh character and direction. But the larger number of them are now engaged in creating new economic forces that suddenly revolutionise the lives of the people. The great inventor has become the real governor of our world.

Producing a steam-engine and attaching it to a mass of wheels and rods of various kinds, he changes in a few years a race of farmers into a nation of townspeople, working in factories, mills, and offices. By putting the steam-engine on wheels he transforms a town of five hundred thousand people into an enormous city with nearly seven and a half million inhabitants. Then he brings them cheap food from the ends of the earth with remarkable swiftness by fitting a screw to the shaft of his steam-engine, and putting this new contrivance into huge iron ships that strangely float like corks on the stormiest seas.

Already it can be foreseen that the inventor will one day endow the human race with such an abundance of cheap power that poverty and want will be abolished. When the hidden store of electrical energy in a pebble of common stone can be easily released and used in lighting the whole of London for a day, or driving for the same period all its systems of locomotion, the difference between the richest and the poorest will be little more than the difference between a happy sufficiency and a proud but empty luxury. Deep and widespread as is the social misery at present caused by the unregulated economic forces of our age, this misery will neither endure nor increase. Perhaps modern wealth will change hands many times before the productive inventiveness of the human race makes all the means of living so cheap and common that a farthing will buy more than a hundred pounds now can. Yet the disorders of the present age are merely the disorders of a period of rapid and complex transition from general poverty to general wealth.

Man is not winning his new and enormous store of riches from his fellow-men, but obtaining it from the natural resources that he has neglected. For a million years the human race has starved in the midst of plenty. Above it and around it and beneath it was all that was necessary to make its life happy; but in their blind stupidity men fought with each other for a scrap of food instead of employing their noble powers of mind in discovering the illimitable resources surrounding them.

And how wastefully we are still using the new means of life that we have recently found! It is a hundred and thirty years since James Watt made an engine that

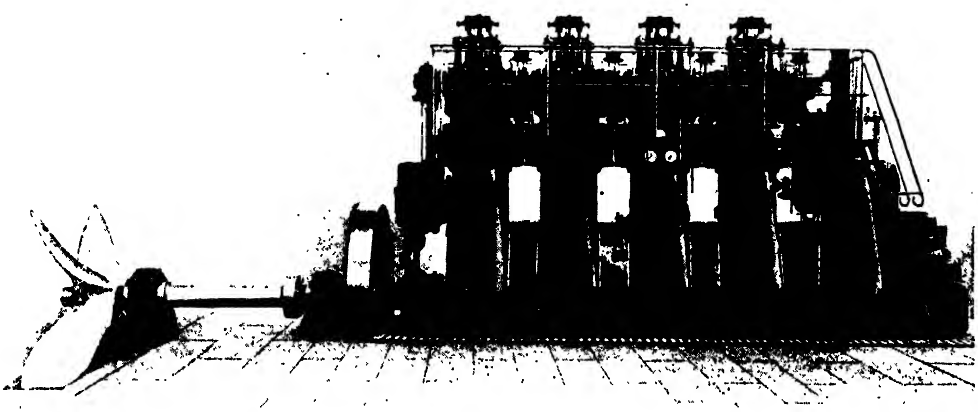
enabled us to turn coal into a generally useful kind of mechanical power. Yet scarcely any advance has been made on the principle on which the Scottish inventor worked. Instead of converting in some direct way the heat-energy of coal into mechanical power, Watt transformed it into steam, and used the energy of the steam in driving a piston up and down an iron drum. Scarcely 6 per cent. of the power stored up in the coal was extracted and employed in actual work. The best steam-engines of the present day, using superheated steam, and making the best of its force of expansion, hardly render available more than from 10 to 15 per cent. of the power in the coal. That is to say, eighty-five per cent. of the work done by our miners is wasted work. Say that they bring up to the mouth of the pit a million units of energy. Well, a good deal less than fifty thousand of these units is actually converted into power for useful purposes in our houses, furnaces, mills and factories, railways and steamships. The greatest waste occurs in our household grates, but the ordinary steam-engine is also a terrible spendthrift of our principal natural resources.

Many years ago a great French man of science—Carnot—took up the study of the problem of converting heat into mechanical energy. He pointed out that a perfect engine would be able to transform a certain quantity of heat into mechanical work, and then use that mechanical work, if necessary, in producing the original quantity of heat. The thing, of course, is utterly impracticable, for much of the heat used in an engine is bound to be lost in various ways. Indeed, water-jackets have often to be employed to prevent the great amount of wasted heat from interfering with the working of the engine. Still, Carnot's ideal engine gave ordinary engineers a standard of perfection which they could at least endeavour to approach as near as their materials admitted. None of them, however, seems to have gone back to the first principles from which Carnot started. They merely kept to the engine that Watt had invented, and worked out a long series of small improvements on it. In short, the science of the prime mover was divided from the practice of machines for producing power.

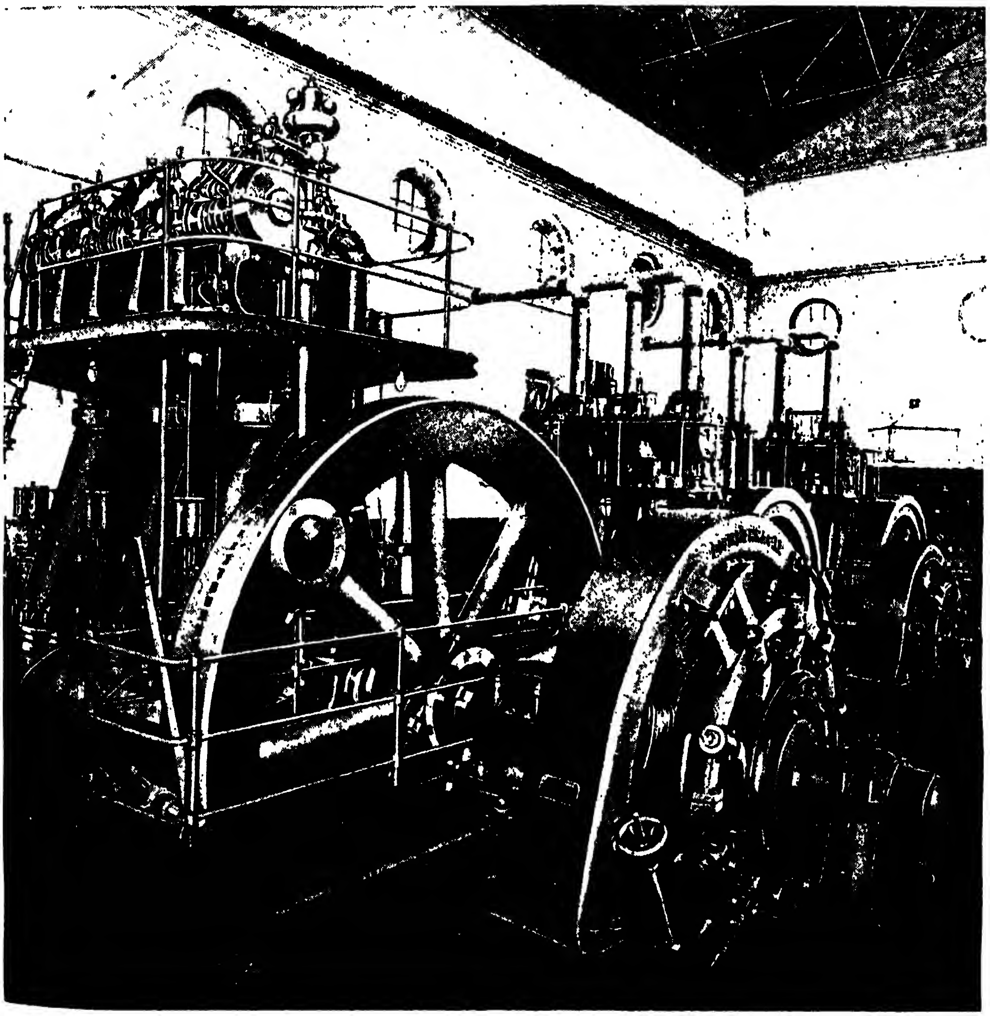
This was especially the case in Great Britain, where the work of Carnot was splendidly continued by Joule and Lord Kelvin, without effecting any practical enlargement of the aims of builders of engines. Everybody admitted that, as a matter of theory, the conversion of the heat energy of coal, first into steam, and then into mechanical work, was a very roundabout process. But, as a matter of practice, everybody except Sir Charles Parsons was content with the principle of the steam-engine. Even Sir Charles Parsons did not see how coal could be transformed into work without the agency of steam; and in 1884 he built his first steam-turbine and began to revolutionise the industrial world.

THE NEW PETROL ELECTRIC CAR ON THE GREAT CENTRAL RAILWAY

But in that year a young and unknown man in Paris was spending a great deal of midnight oil in a determined effort to go clean behind every principle of the steam-engine, and do away entirely with the necessity of using boiling water in getting mechanical work out of fuel. The young man was Rudolf Diesel, born of German parents in Paris in 1858. In spite of his youth, he was the manager of a French company for building Linde's refrigerating



A REVERSIBLE DIESEL MARINE ENGINE OF 1000 BRAKE HORSE-POWER



DIESEL ENGINES THAT GENERATE POWER FOR DRIVING THE TRAMWAYS OF CALCUTTA

machinery. He had studied in Paris until 1870, but when the Franco-German War broke out his parents emigrated to England, and sent their boy to school at Augsburg, in Bavaria. There he distinguished himself in the technical school, and attracted the notice of Professor von Linde; and the famous German man of science induced the brilliant lad to take the new science of thermo-dynamics as his principal study.

Now, thermo-dynamics is merely the science founded by Carnot, dealing with the application of the principles of mechanics to heat production. So, just at the most impressionable time of his life, Diesel became acquainted with the ideal engine imagined by Carnot; and with the enthusiasm of youth he resolved to dedicate all the powers of his mind to the problem of approaching a perfect engine for transforming heat into work. By a happy chance he was able to combine mathematical theory with practice in invention. For Professor von Linde was then engaged on those researches into liquid air which have made his name famous throughout the world; and when Diesel was only twenty-one years of age he was appointed to assist his master. The work was very interesting, and it had a direct bearing on the idea that filled the mind of the young assistant. In order to liquefy the gases of the air, it was necessary to devise a means of robbing them of their heat. This was just the reverse of what takes place when liquid matter is converted into a gaseous state. Thus, Diesel was able fully to study in Linde's laboratory all the scientific details of a process similar yet opposite to that which would take place in the engine he was dreaming of.

When his master was satisfied that he had grasped all the difficult ideas of the new science of thermo-dynamics, the young inventor had a short period of practical work in the machine-shops of Sulzer Brothers, in Winterthur, in Switzerland. But by this time Rudolf Diesel had not much to learn in practical engineering, as he had already done a good deal of work in helping Linde to develop his ice and refrigerating machines. So he was soon promoted to the managership of the Paris company for the construction of refrigerating machinery. It was then he began seriously to carry out his search for a prime mover of much higher efficiency than the steam-engine. For years he spent his evenings and his nights in working out on paper intricate scientific calculations in various forms of engines. And just about the time when Sir Charles Parsons in England was developing the steam-turbine into a really practicable prime mover, Rudolf Diesel abroad worked out on paper the principle of a new engine which now threatens to throw every kind of steam-engine on to the scrap-heap.

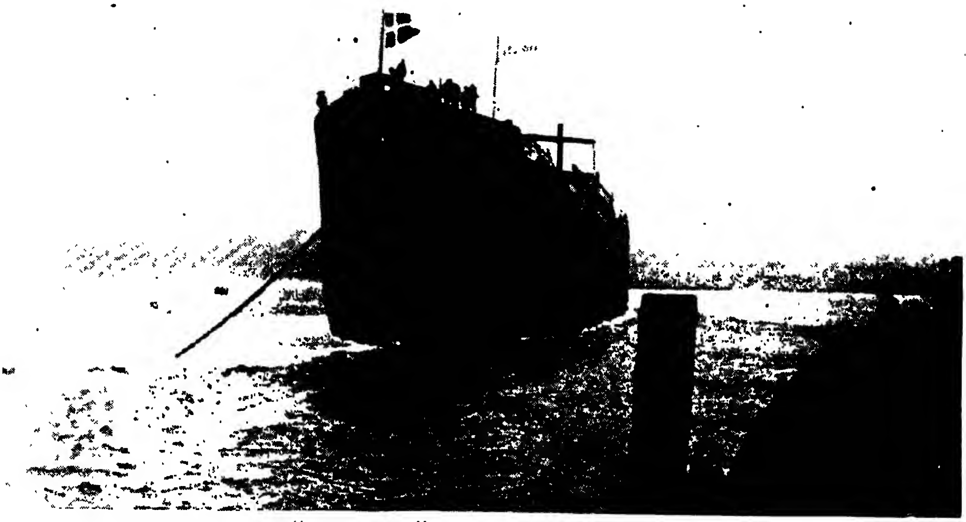
DR. RUDOLF DIESEL

The young inventor was not rich enough to build his new engine, though in 1892 he began to construct a small experimental model. So he decided to appeal to the public by a small book entitled "The Theory and Construction of a Rational Heat Motor." This book was published in 1893. Writing both as a man of science and as a practical engineer, Diesel showed clearly how the new science of thermo-dynamics had outstripped all workshop practice; and he gave an outline of an astonishingly original engine which, in theory, should be at least three times as efficient as the very best of then existing steam-engines. His ideas were stated with some sharpness and force, and they attracted the attention of many engineers in Germany. There was a somewhat heated discussion on the matter in the technical Press, which, instead of hurting the fame of the young and audacious man of science, excited interest towards him.

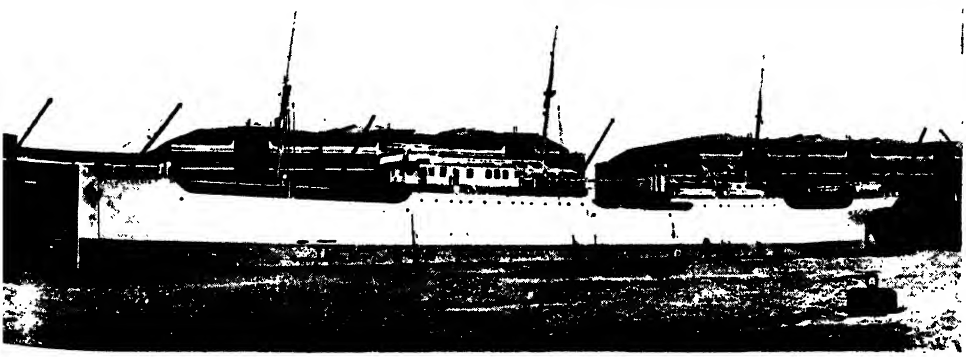
He promised so much, and, after all, the expense of testing his ideas was practically

THE COMING OF THE REVOLUTION SHIP

THE LAUNCH OF THE OIL-DRIVEN SHIP "SELANDIA" AT COPENHAGEN

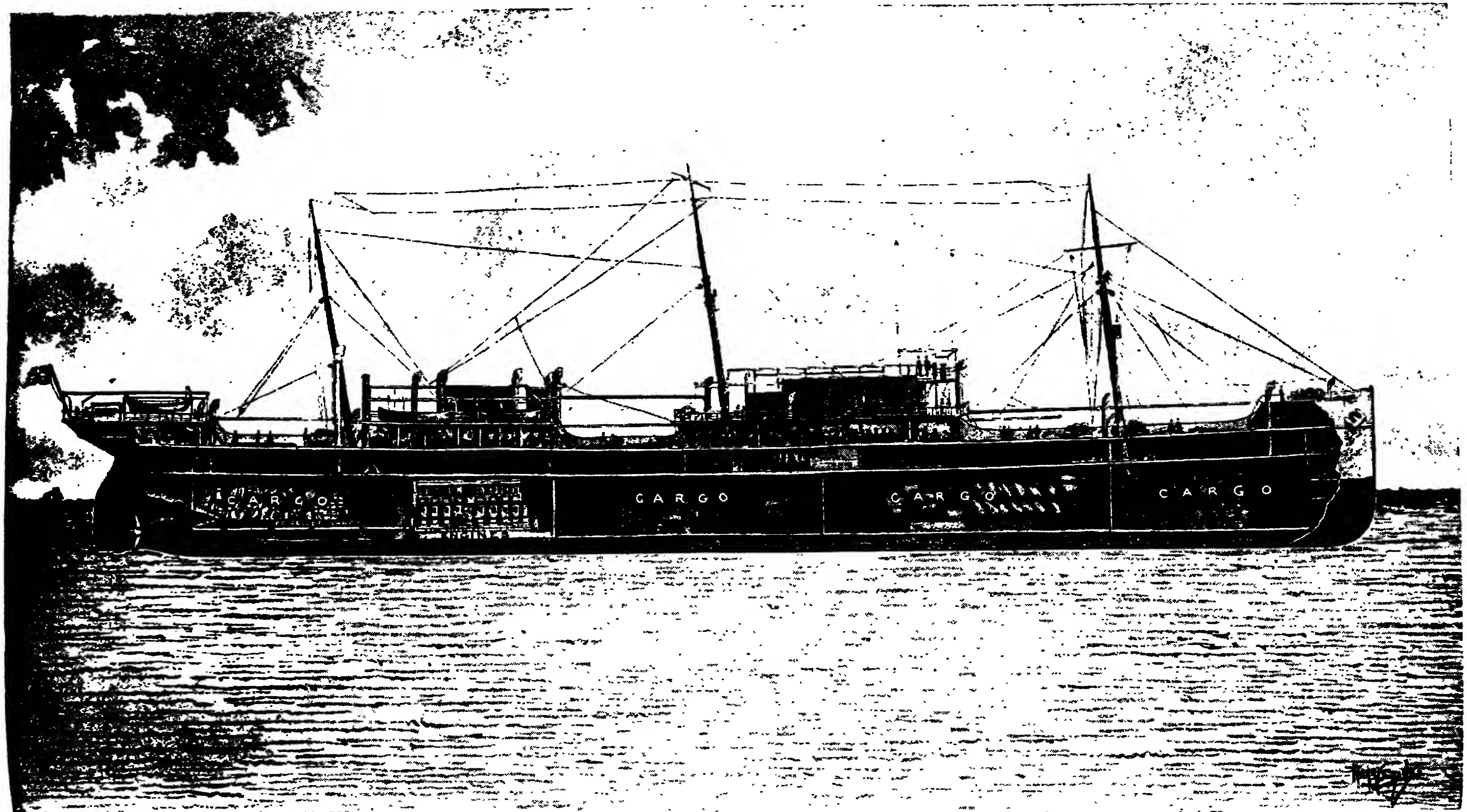


A VIEW OF THE "SELANDIA" JUST AFTER IT HAS BEEN LAUNCHED



ANOTHER VIEW OF THE SMOKELESS "SELANDIA," LYING IN THE THAMES

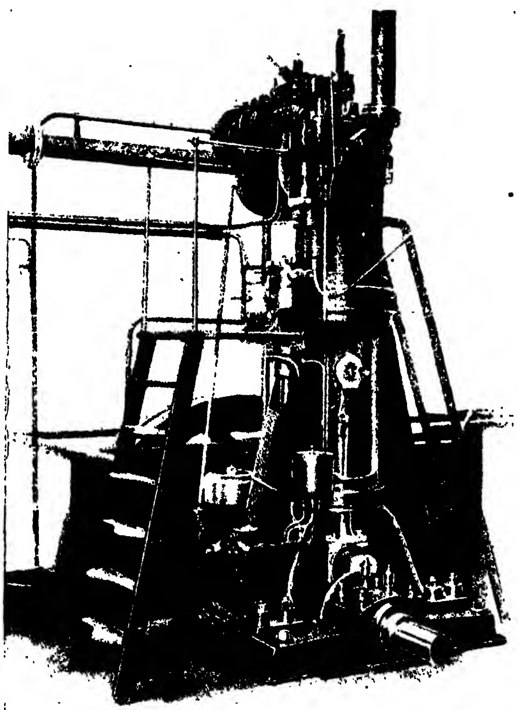
INTERIOR VIEW OF THE OIL-DRIVEN "SELANDIA," SHOWING HER CARGO CAPACITY



This sectional drawing of the Diesel engine-ship, with the water-line purposely lowered to admit of observation, makes clear the smallness of the space

nothing to a large manufacturer. So Friedrich Krupp, the steel king, and H. Buz, the chairman of the Augsburg Machine Works, resolved to see if there was anything in the young inventor's ideas. They gave him the means for the practical development of his engine; and in 1897, at a meeting of the National Society of Engineers of Germany, Diesel read another pamphlet explaining his ideas.

This time he was not obliged to attempt to prove on paper what his engine was capable of doing. He described what it had done, and invited all persons interested in the matter to test for themselves the extraordinary efficiency of the actual engine that was working at Augsburg. After four years of difficult experiment he had succeeded in making his new prime motor far more efficient than any gas-engine or petrol-engine or steam-engine. Scarcely anyone in Great Britain except Lord Kelvin was immediately interested in the new invention. Kelvin, however, was very enthusiastic, and he strongly recommended a Glasgow firm of engine-makers, Messrs. Mirrlees, Watson, and Co., to take up the Diesel engine. They did so, and in 1897 built a small motor on the new principle, which is still working admirably at Stockport.



THE FIRST DIESEL ENGINE MANUFACTURED IN GREAT BRITAIN

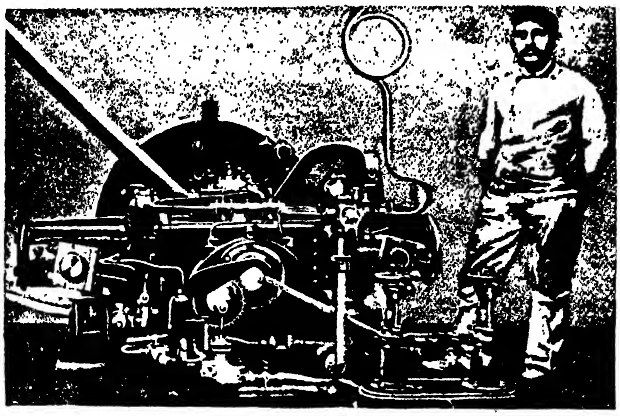
This engine was built in 1897 by the Mirrlees, Watson Company of Glasgow, and is still working.

Supposing it were announced that all the wealthiest men in the world had combined together to endow the human race with their riches, the event would be of less importance than the discovery of the Diesel engine. It has doubled, and perhaps trebled, the amount of power actually possessed by mankind. It needs only the cheapest and crudest kinds of fuel the thick residual oils left after distilling and extracting the finer products of petroleum, and the tar and tar-oils remaining after the manufacture of coke and various chemicals now obtained from coal. The new engine can also be run on vegetable oils, made from ground nuts and other abundant and disregarded products of our tropical and colonial possessions. In all cases the weight of the fuel is from one-fourth to one-sixth the weight of coal. Thus, in addition to its other advantages, the Diesel engine greatly reduces the cost of transporting the materials from which power is obtained. It is already revolutionising our Merchant Service and our Navy, and giving so enormous a stimulus to the development of the petroleum industry that it is likely that coal will become of less importance than oil. For recent geological researches prove that there is more liquid fuel on our globe than coal, and, moreover, the oil-fields are more conveniently distributed.

On the other hand, the new engine does not interfere with the advantages that Great Britain possesses by reason of its extraordinary coal resources. It makes coal a far more valuable material than it was in the days of the steam-engine. A few months ago Sir William Ramsay pointed out, in his address at the British Association for the Advancement of Science, that in less than two hundred years the coal mines of our country would be utterly exhausted. His calculations were based on the presumption that the wasteful steam-engine would continually be used in converting a fraction of the heat of coal into mechanical work. Dr. Rudolf Diesel, however, has now worked out another method for using the wealth of energy contained in our coal-mines; and last March he came to London and explained his views at the Institute of Mechanical Engineers. If he is correct in his calculations with

regard to his engine, our coal resources will last us for another four hundred or five hundred years. All our coal should first go into gasworks or cokeworks with modern installations. There it should be turned into coke and various chemicals, leaving the tar and tar-oil. This residue can be used in a Diesel engine with the extraordinary advantage of being much better than coal is when used in the ordinary steam-engine. At the Turin Exhibition last year a steam-turbine and a Diesel engine, both built by one maker, were shown working with liquid fuel. The turbine occupied a much larger space, and consumed two and a half times the amount of fuel used in the Diesel motor, and yet it did no more work.

An admirable feature of the new engine is the simplicity and compactness of its construction. No boilers of any kind are needed, and neither furnace nor chimney is necessary. It is somewhat like the petrol-engine used in motor-cars, motor-'buses, and flying-machines. Like them, it is a development of the principle of the Otto gas-engine. In its original form, the new prime mover has a four-stroke cycle. That is to say, four strokes of the piston working in the cylinder are necessary to create one movement of energy. The first stroke is a suction stroke. The piston moves downward, creating a vacuum in the cylinder, with the result that air is sucked in direct from the atmosphere through a valve. At the end of the stroke the cylinder is full of pure air. The next stroke is the compression stroke, which constitutes the original feature of the Diesel engine. The piston returns into the cylinder, forcing back the air, but the valve is now closed, and the air cannot escape. The atmosphere is thus compressed with a pressure of five hundred pounds to the square inch. Under this great weight the air becomes very hot, the temperature rising to as much as 1000 degrees Fahrenheit.



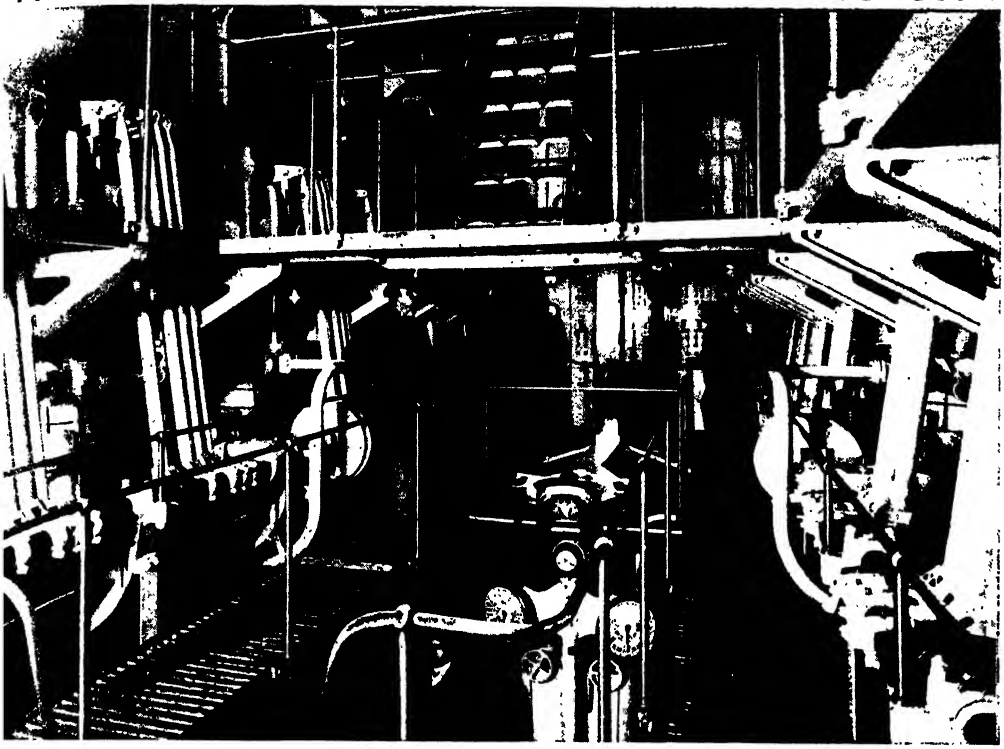
THE FIRST DIESEL MARINE ENGINE, BUILT IN 1902

It is here that the science of thermodynamics comes in. The compressed air is now like a coiled spring, full of restrained energy, and a considerable part of this energy is transformed into heat. The heat would be wasted if the remaining energy were merely used in driving the piston forward. But a valve is now opened in the cylinder, and a stream of fine liquid fuel is injected. This catches alight when it reaches the hot compressed air, and the energy of the combustion, combined with the force of the compressed air, sends the piston forward on its grand working stroke. In the fourth and final stroke the burnt gases are expelled from the cylinder into the exhaust pipe, and the cycle of operation begins once more, for the empty cylinder is now ready to receive a further charge of air on the next out-stroke of the piston.

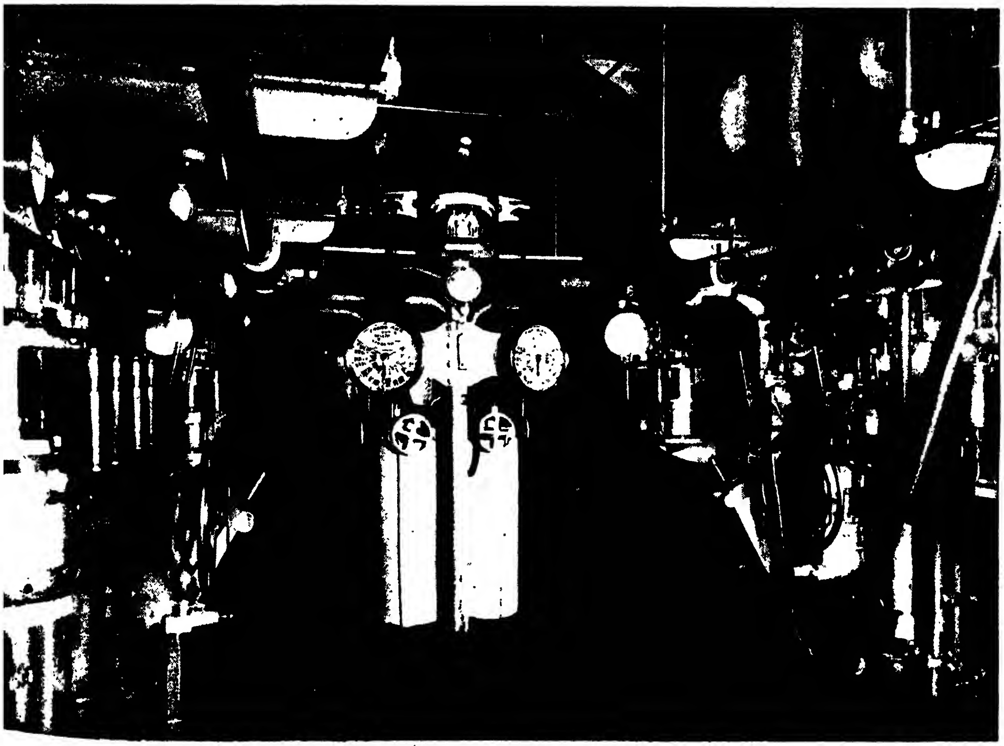
The great difference between a Diesel engine and a gas or petrol engine lies in the use of pure compressed air. In a gas or petrol motor the air is mixed with the gas or vaporised oil, and the two form a highly explosive mixture. The explosion is produced by an electric spark, or some other form of ignition. Motors of this kind are often called internal-combustion engines. This, however, is quite a wrong term for them. They are pure explosive engines, worked by the firing of an explosive mixture of air and gas, or air and vaporised oil. They are the practical realisation of the engine worked by gunpowder, which some inventors of the seventeenth century vainly tried to make safe and regular in action.

The Diesel motor, on the other hand, is a real combustion engine. It realises the dream of a number of men who tried to get a fire inside a kettleful of water, instead of keeping the kettle on the fire, as James Watt did in his steam-engine. Dr. Rudolf Diesel has got over the difficulty by filling his kettle full of hot air, and then squirting some oil or tar into it. The fuel does not explode, but burns properly. In this way the energy of the fuel is obtained in a gradual

THE ENGINE ROOMS OF A STEAMLESS SHIP



THE UPPER ENGINE-ROOM OF THE DANISH MOTOR-SHIP "SELANDIA"



THE LOWER ENGINE-ROOM OF THE SPOTLESS "SELANDIA"

and regulated manner, as in a furnace, instead of being swiftly and violently liberated as in an explosive engine. The result is that less energy is wasted in the heat that now spreads through the metal of the cylinder and piston, and makes the working parts dangerously hot.

Both the Diesel engine and the gas-motor are more economical than any form of steam-engine. They save the heat and energy that is lost when the power derived from coal travels from furnace to boiler, from boiler to cylinder, and also up the chimney. In the new engines, all the work of producing power is performed in the closed chamber formed by the top of the cylinder and the disc of the piston. The heat which can be lost by radiation is comparatively small; and it is only when the burnt and used gases are expelled from the exhaust-valve that a considerable amount of energy is thrown away. Perhaps, when very large Diesel engines are built, means may be found of conveying the exhaust gases to some secondary kind of contrivance which will make use of them. This is being done with the waste steam from large steam-engines, the by-product being employed for driving electric fans or heating purposes.


BECALMED NO MORE—THE SCHOONER "SOUND OF JURA," PROPELLED BY HER OIL-ENGINES

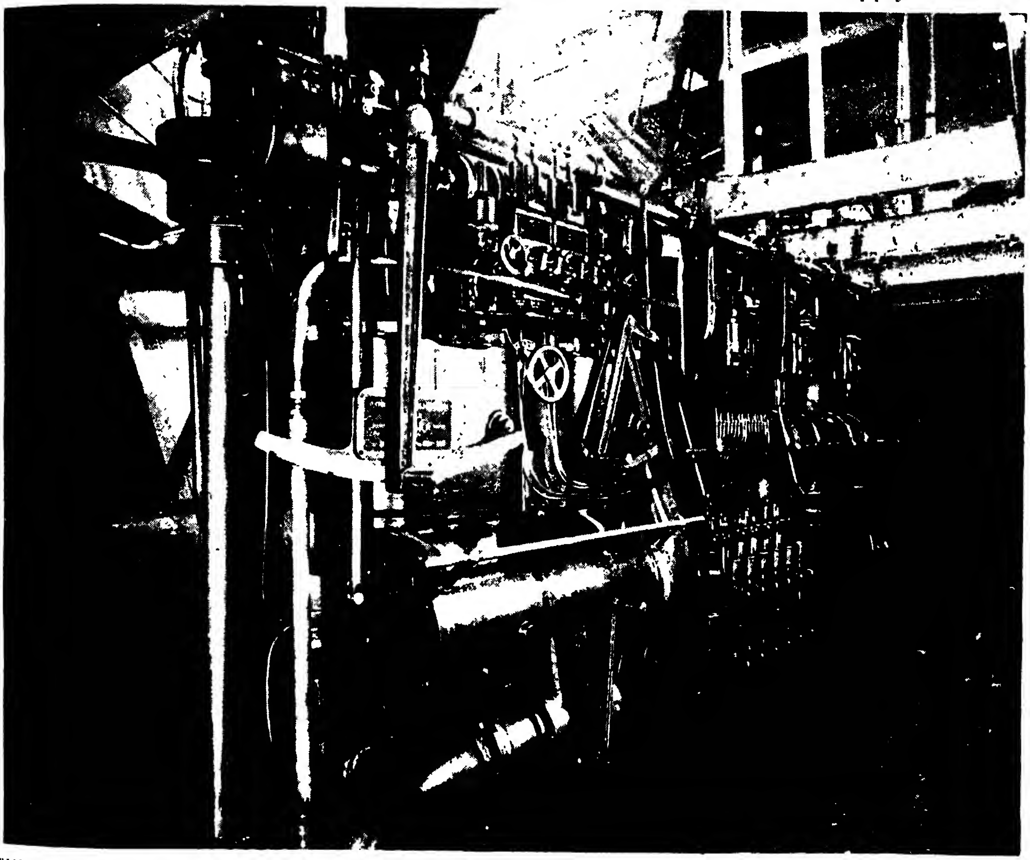
But even as the Diesel engine now stands, it is the nearest approach to Carnot's standard of perfection. It converts into mechanical work a larger percentage of the energy of fuel than any other form of prime mover. The effective efficiency of non-condensing steam-engines is at best scarcely $8\frac{1}{2}$ per cent. That of condensing steam-engines and turbines using superheated steam is from 10 to 15 per cent. The effective efficiency of modern suctio[n] gas-engines is from 18 to 23 per cent. But that of the Diesel engine now is from 3[2] to 34 per cent., and already some of the finest types show an effective efficiency o[f] 35 per cent.

Figures like these talk, and engineers al[l] over the world are eagerly listening to them. As it is open to any firm of engine-builders to make use of Dr. Diesel's ideas on paying him a royalty, the construction and the improvement o[f] the new engine are proceeding with remarkable speed. The possibilities o[f] the invention are far from being exhausted; and hundreds of younge[r] inventors are now busy applying th[e] principle in new ways. For instance it is just reported that an Englis[h] engineer, Mr. Frederick Tanner has devised a Diese[l] engine with tw[o] strokes, which is [a] marvel of simpli[fied] and scientifi[c] design. He [is] getting excellen[t] results without th[e] complicated part[s] used in the Continental forms [of] Diesel engines. D[r.] Diesel himself [is] engaged in design[ing] a very sma[ll] and cheap engin[e] for farmers tha[t] will do the work [of] five horses at le[ss] expense than [it] costs to keep a donkey. It is expected tha[t] small manufacturers will find this engine ver[y] useful, and it should be valuable in helpin[g] to revive all kinds of village industries.

It was the big steam-engine, cumbersome expensive, and terribly wasteful of powe[r] which produced the worst effects in th[e] industrial revolution. By destroying th[e] village industries, it broke the prop o[n] which the small peasant proprietor leane[d] when he could not work on his fields; an[d]

it attracted all our broken agricultural labourers into the great factory towns. Now, a small, cheap Diesel engine, running on crude oil or tar-oil, would be as helpful in small peasant industries as the sewing-machine is in home work. Probably it would cost no more in actual value than the handlooms which, at the beginning of the eighteenth century, were scattered all over the country-side.

At present the two-stroke Diesel engine seems the most promising form of the new cylinders, with, however, common exhaust-ports. In this case, the air is injected first above and then below by a pump. As the piston moves backwards, it compresses its air, and the fuel is at once injected and burnt, creating an expansion of gas which sends the piston upwards. Here it again compresses the air sent in by the pump, and the fuel arrives just at the instant when the burnt gases in the lower part of the cylinder have been expelled through the exhaust-ports, and a new supply of air has



THE ENGINE-ROOM OF THE SAILING-VESSEL "SOUND OF JURA," ON THE OPPOSITE PAGE SHOWING THE 260 H.P. POLAR-DIESEL ENGINE USED DURING CALMS OR CONTRARY WINDS

prime mover, and Dr. Rudolf Diesel himself inclines to the belief that it will prove the most serviceable type. In the two-cycle, double-acting engine, each stroke is a working stroke. The cylinder is divided into two parts by openings in the middle, through which the burnt gases escape. These openings are called exhaust-ports. There are two sets of valves, for drawing in air and admitting fuel. One set is at the bottom of the cylinder, and the other set is at the top. Thus there are practically two

been sent in by the pump. So combustion then takes place in the upper part of the cylinder, giving the piston another working stroke, which also compresses the air in the lower part of the cylinder. Thus there is a continual to-and-fro movement of the piston, similar to that which occurs in a reciprocating steam-engine.

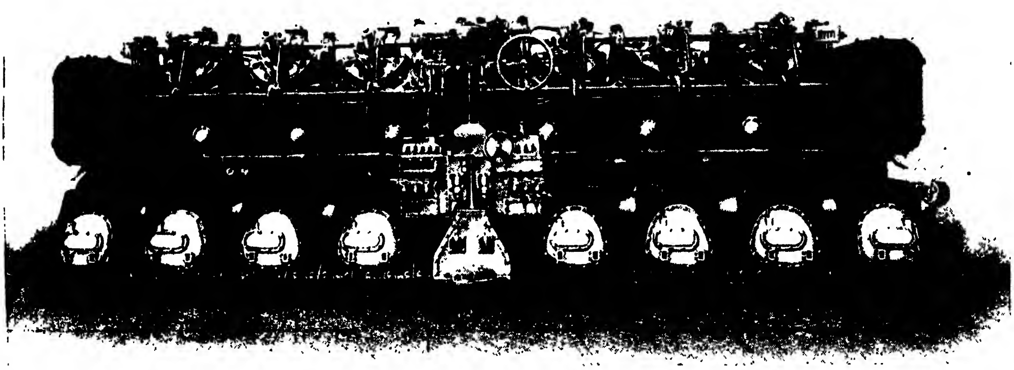
The unusual thing about a Diesel engine is its air-compressor that works the fuel supply. It was the design of this part of his invention that gave Dr. Diesel most

trouble. He had to get a thin stream of liquid fuel into a closed chamber, in which the air had already been compressed five hundred pounds to the inch. It was necessary to use very great force in injecting oil or tar against so enormous a resistance. It could only be done by spraying the fuel in with a blast of air that was much more compressed than the air in the cylinder. This is what makes the Diesel engine look so complicated a piece of mechanism. There are various attachments, so to speak, to the main shaft, which is worked direct by the to-and-fro movement of the piston in the cylinder. One of these attachments takes away a portion of the power, and uses it for compressing the air in the machine that sprays the fuel into the cylinder. Another attachment takes a little of the power, and gives it to the pump that pumps into the main cylinder the air which the piston compresses and makes hot and ready to burn the fuel.

Yet the energy that is taken away to work the fuel-injector and the pump is not lost to the engine. A great deal of it comes back in the enormous pressure with which the fuel is injected, and this pressure helps to drive forward the piston. Then the pump also partly compresses the air with which it deals, and thus saves the piston some part of its preparatory work. It is this economical design of all the working parts of a Diesel engine which makes it so wonderfully efficient a motor. The main principle is so simple and scientific that the engine itself, in spite of its complicated appearance, is easy to understand and easy to work. Indeed, one of its great practical advantages is that a single man can look after a large engine. This, combined with the saving of space effected by doing away with boiler-room, furnace-room, and coal-bunkers, makes the Diesel engine as important on sea as it is on land.

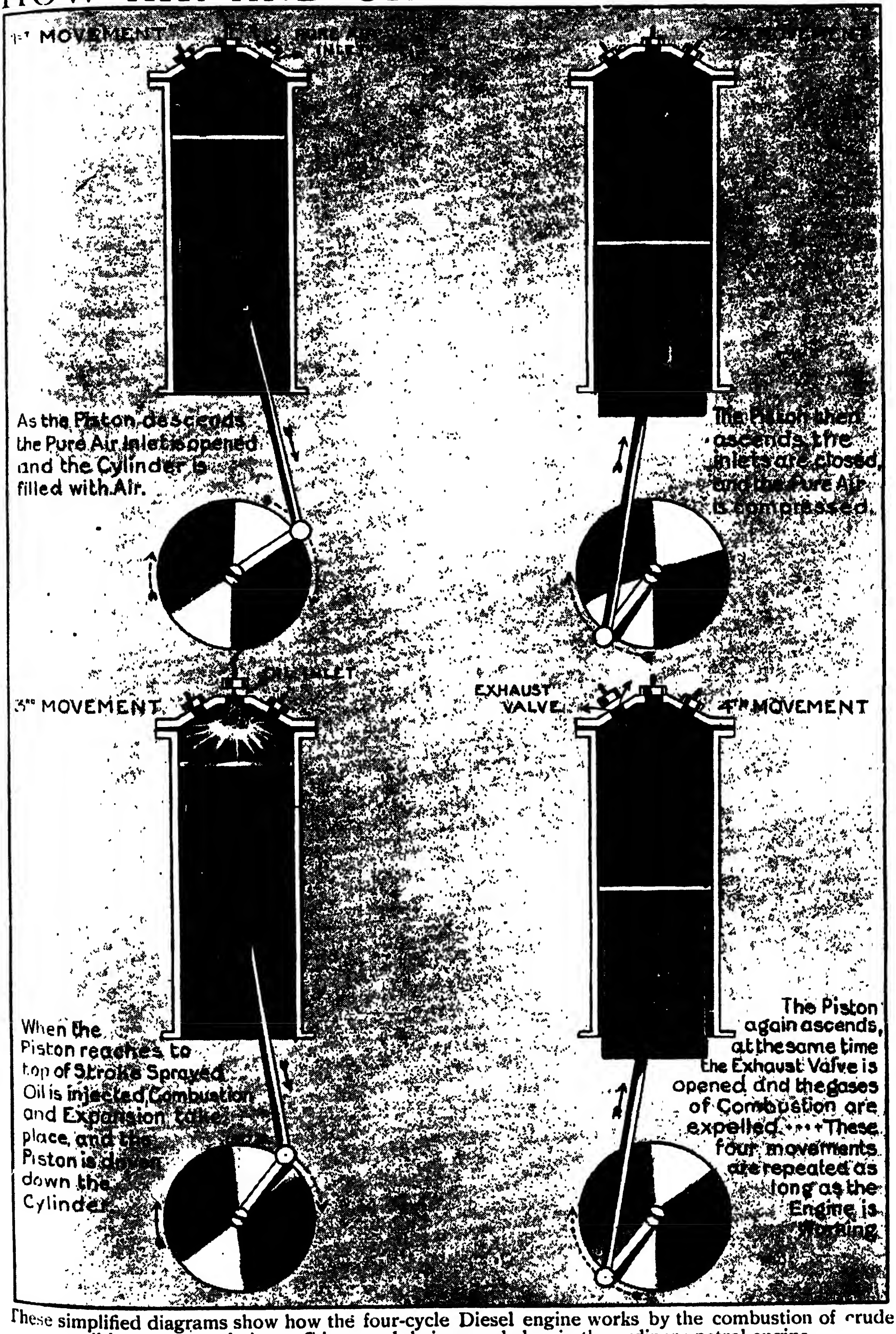
It is scarcely a month since the great new motor-ship the "Selandia" made her first voyage from Denmark to London. Built by Mr. John W. Wainwright, of Burmeister and Wainwright, a Copenhagen firm that now thinks of taking a building-yard on the Clyde, the new ship excited wide and profound interest in our country. The First Lord of the Admiralty inspected it, and one of our admirals voyaged on it to study the working of its great Diesel engines. The residual oil which it carried as fuel was only about one-fourth the weight of the coal that would have been required to drive a steamship of the same tonnage and capacity. Moreover, it was found that this liquid fuel could be stowed in the keel of the motor-ship—a place which, on an ordinary boat, is useless for cargo and remains empty. Being built for the carrying trade, the "Selandia" is not as quick as a liner. Like other cargo-boats, it is designed to go at a slow and steady speed under a very heavy burden. So its Diesel engines only develop two thousand five hundred brake horse-power. But the fuel it uses is less than that which the builders guaranteed it would use. That is to say, it is more economical in running expenses than its builders expected.

The vessel has a length of 370 feet, a breadth of 35 feet, and a depth of 30 feet; and it is designed with a dead weight carrying capacity of 7400 tons It has two Diesel engines, driving a pair of twin propellers. It looks curiously like a sailing-ship, by reason of the fact that it has no



THE NEW DIESEL OIL-ENGINE BUILT FOR A SUBMARINE
This six-cylinder reversible oil-engine, built by Messrs. Krupp, develops the power of a thousand horses.

HOW AIR AND OIL DRIVE AN ENGINE



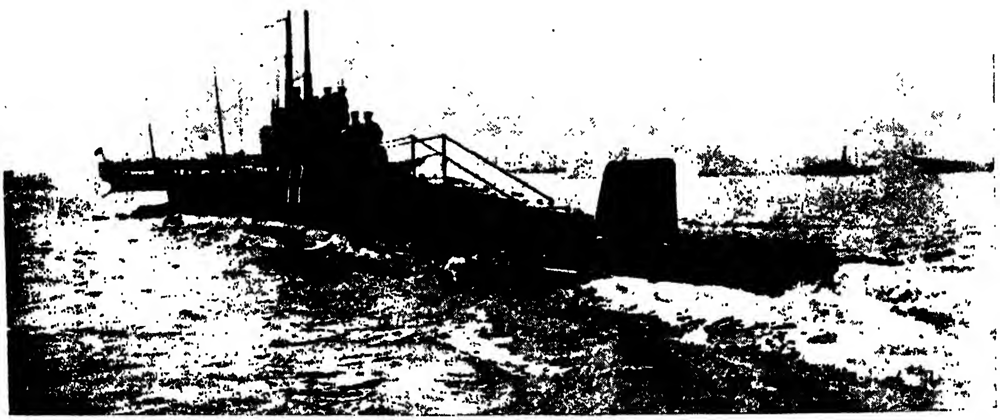
These simplified diagrams show how the four-cycle Diesel engine works by the combustion of crude oil in compressed air, no firing-spark being needed as in the ordinary petrol engine.

funnel and makes no smoke, but keeps three masts in the old-fashioned manner. The exhaust gases escape from the top of the masts; and as the oil is stowed in tanks in the keel, the space usually required for coal-bunkers is available for cargo. Thus the motor-liner is more profitable than the steamship in three ways: her engine-room staff is smaller, her capacity for cargo is greater, and every day she saves the difference between ten tons of crude oil or tar-oil and forty-five tons of coal.

As we go to press we hear from the Red Sea that the engines of the "Selandia" are working perfectly, and that everything is satisfactory. The engineer has practically nothing to do. He can sit down comfortably in his clean, bright engine-room and read a book. There is no smell from the oil, as there was in the smaller motor-ship, the "Vulcanus," that Sir Marcus Samuel had built for the Shell Transport and Trading Company. Yet it must in fairness be pointed out that the "Vulcanus," a British-owned boat, was built long before the Danish vessel, and it has been running successfully for the last fourteen months or so. In the opinion of Sir Marcus Samuel, the marine steam-engine is dead; and if our shipbuilders and shipowners do not quickly become aware of this fact, the countrymen of Dr. Diesel will be able to use the new engine in overthrowing the supremacy of our Mercantile Marine.

Already two motor-liners have been built in German yards for the Hamburg-America line. The saving in fuel and the gain in storage space effected on these vessels will enable the owners to cut cargo and passenger rates to a point at which no steam liner could profitably be run. The motor-ships will, moreover, be more pleasant to voyage on. In place of the great smoke-stacks, there will be a level and spacious promenade deck, suitable for roller skating or afternoon teas in the summer. Or, if ocean travel becomes still more luxurious, there may be tennis-courts or croquet-lawns. The change below deck in an "oiler" will be still more remarkable. The great furnace-rooms and the boiler-rooms will disappear. So will the coal-bunkers; and the engine-room will shrink to half its former size. The dozens of half-naked firemen toiling at the furnaces, and the crowd of coal-passers in the bunkers, will vanish, and a few engineers will manage the pumps that lift the oil from the bottom of the ship, and look after the air-compressors and the engines. When the motor-liner ends its outward bound journey, there will be no grime and toil and flurry of coaling, for probably no more fuel will be needed. Even if it is, a pipe and a pump will do the work cleanly and automatically in a short space of time.

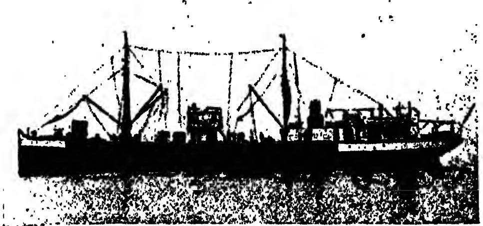
Sailors of the old school are beginning to take an especial interest in the Diesel engine. For it is very likely that the new motor will bring back on the seas the picturesque sailing-ships that were so largely and widely displaced by the steamer —the gallant old "wind-jammers," riding proudly under full sail and making use of

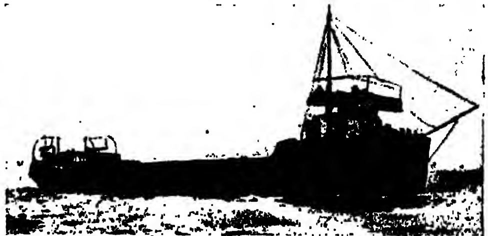


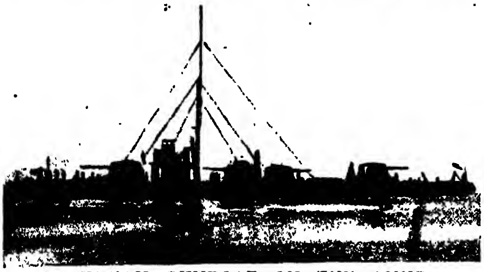
THE NEW TERROR ON THE HIGH SEAS—A SUBMARINE DRIVEN BY OIL

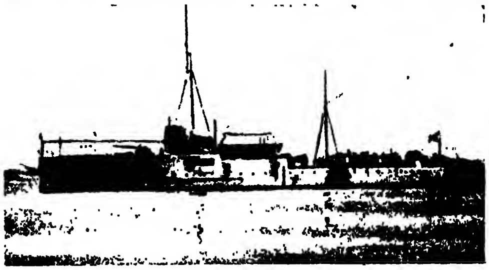
The new motor-power has revolutionised the sea-going potentialities of the submarine. The D7 here shown is propelled, when on the surface, by Diesel oil engines of 1200 horse-power, at a speed of sixteen knots an hour, and carries sufficient fuel to travel 4000 miles. Under water this vessel is driven by electric motors deriving their current from storage batteries.

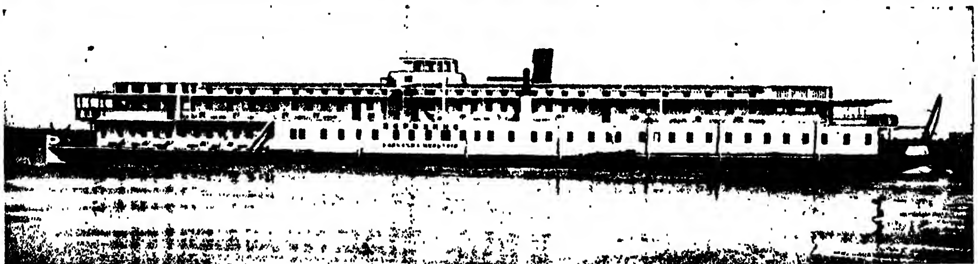
PIONEER SHIPS OF A NEW ERA


THE MOTOR TANK-SHIP "VULCANUS"

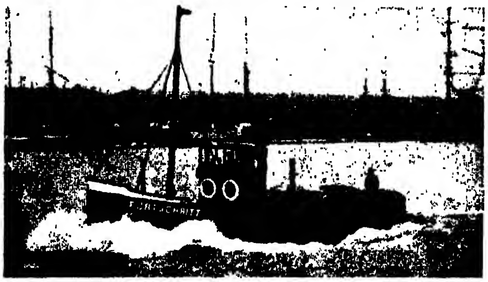

THE "TOILER," A CARRIER ON THE GREAT LAKES

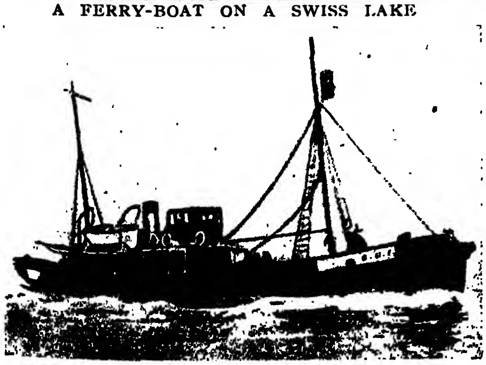

A RUSSIAN GUNBOAT ON THE AMUR


A GUNBOAT ON THE CASPIAN SEA


THE TWIN-SCREW "BORODINO," A RUSSIAN MAIL AND PASSENGER SHIP


A FERRY-BOAT ON A SWISS LAKE


A TUG USED AS AN ICE-BREAKER


A MOTOR WHALING-SHIP


THE POLAR SHIP "FRAM"

SOME EARLY SHIPS DRIVEN BY OIL, THE PROBABLE DOMINANT MOTIVE POWER OF THE FUTURE

These photographs and others on these pages are reproduced by courtesy of "The Motor Boat" and Mr. R. W. Crowly. Acknowledgment is also due to Messrs. Burmeister and Wain, The Diesel Engine Company, Mirrlees, Bickerton and Day, and "The Engineer."

the cheapest source of natural energy in the world. Fitted with the new engine, that requires so little room for itself and its fuel, the great, full-rigged clipper will be able to carry cargo more cheaply than the steam-tramp, and at the same time she will be as speedy as her rival. For in a fast and favouring wind she will trust entirely to her sails; and when the wind drops, her Diesel engine will be set to work. The space now wasted in her double bottom will easily contain the liquid fuel she needs, and the small engine-room will not seriously interfere with her capacity for storing cargo.

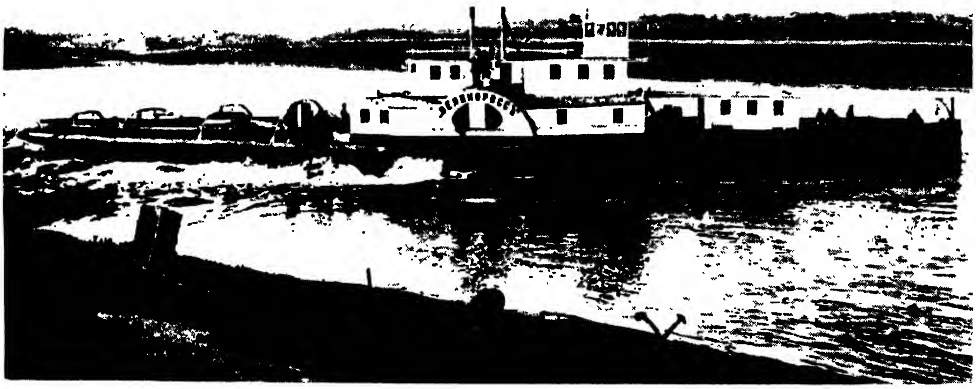
So here is another very important industry, likely to occupy hundreds of thousands of shipwrights and sailormen, which will fall into the hands of the nation that is most alert to develop the new fields of enterprise opened by the engine of revolution. At present France seems to be the country most willing to experiment in oil-engined sailing-ships.

But most important of all the changes in marine affairs produced by the invention of Dr. Diesel is the motor battleship. Here the race is still to the nation with the quickest and largest power of invention. As yet no Diesel engine has been designed for marine purposes with the tremendous horse-power necessary to fling through a stormy sea at thirty miles an hour a floating steel fortress. Yet it is certain that such an engine will be built by one of the great naval Powers in the course of a year or two.

Its advantages would be overwhelming. First, there would be the absence of the huge funnels which are so easy a mark for hostile guns. Holed near the deck by a well-placed shell, the modern funnels would make much of the upper part of the battleship uninhabitable, through the hot fumes and flames escaping from the rent. Already the flame, fifty feet in length, that arose from one of the funnels of H.M.S. "Lion" has upset the fire-control of that battleship, and made her navigation impossible. The Diesel engine, moreover, would make a battleship very much more powerful.

The weight and space saved by doing away with boilers and furnaces and coal-bunkers could be put into additional guns and heavier armour-plate, or the radius of action of the ship could be vastly extended. Possessing a supply of liquid fuel lasting for months, it could range all the seas of the world without having to put in anywhere for new supplies. The rapidity with which a Diesel engine can be started is another factor of importance in connection with naval warfare. It takes about fifteen minutes to get up steam on a steam-engine ship, while an oil-engine vessel only requires five minutes to start. Happily, our Admiralty seems to be as alert to the advantages of the new motor as they were to those of the steam-turbine, and they are now planning a new class of motor-cruisers that can hold the sea for six weeks and more, and protect our food supplies and our commerce.

Having effected a revolution on land and sea, the Diesel engine is now seeking for an opportunity of driving the steam-engine from one of its earliest and most secure of strongholds—the railway. At present the more expensive petrol motor seems to be carrying on the battle for locomotive power. During the recent coal strike the Great Western Railway and the Great Central Railway have been experimenting in oil-



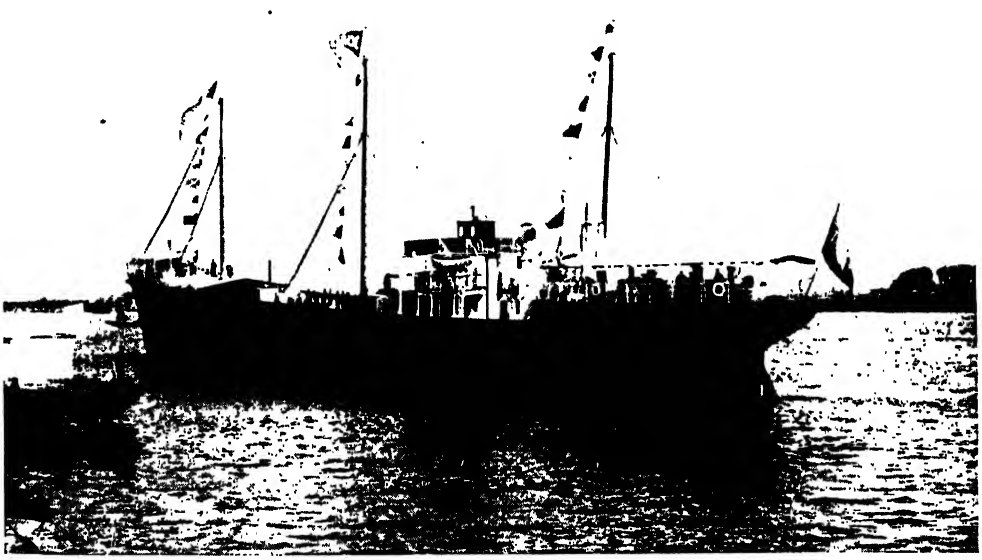
THE OIL-ENGINED PADDLE-TUG "VELIKOROSS," IN SERVICE ON THE VOLGA

driven trains, and the results are very satisfactory. The oil-engine is attached to a dynamo, so that its power can be converted into electrical energy. This is done because electricity is at present the handiest form of power for locomotives, by reason of the ease with which it can be controlled.

Naturally, there is some loss of energy in transforming the mechanical work of the oil-engine into electricity, and then changing the electricity back into the mechanical work that drives the wheels. Yet, in spite of this, the oil-engine is now proving itself a more economical source of power than the steam-engine. It is especially cheaper in light passenger service, and on lines with a long gradient. It climbs better than steam. The new car used on the Great Central Railway carries fifty passengers in two large and well-ventilated compartments, and it runs at a speed of forty miles an hour, and requires only one man for the driving and engine control.

We are inclined to believe that even here the Diesel engine will triumph over both the petrol motor and the steam-kettle. Its varieties of fuel are cheaper than coal and much cheaper than petrol. Then, the mechanism by which its speed of working is governed is calculated to make it the most useful of prime movers. The power that the Diesel engine creates between its cylinder and its piston is directly governed by the amount of fuel injected by the compressed-air mechanism. Attached to this mechanism is a governor which automatically alters the amount of fuel injected. For instance, when the engine is running too fast, the governor diminishes, without any human assistance, the quantity of liquid oil or tar burnt at every stroke. If, on the other hand, the engine slackens, the governor causes more fuel to be injected.

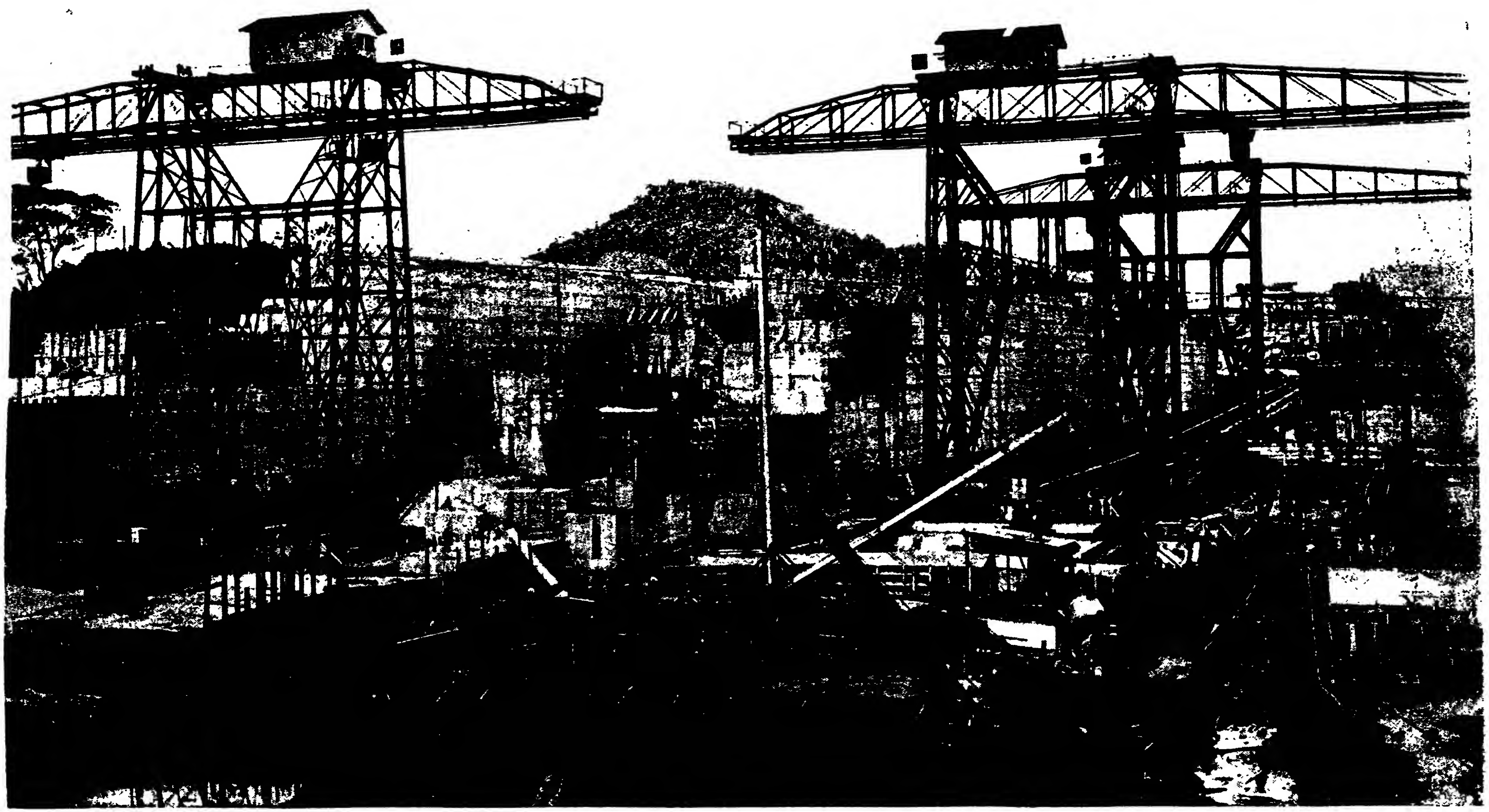
There are some serious mechanical difficulties to be surmounted before the new engine can be directly attached to the driving-wheels of the locomotive; and the electrical transmission of the energy will be necessary until some inventor arrives and solves the difficulties. But a Glasgow firm is now building a Diesel engine locomotive that is worked by compressed air. It is our opinion that the new prime mover, with its cheap fuel and its extraordinary efficiency, will soon make motor traction a serious danger to the railway companies, and a great and widespread benefit to all farmers, merchants, and manufacturers who need a cheaper form of transport than that which now exists. It is also very likely that an oil-engine burning residual fuels will transform a motor-car into a vehicle quite within the reach of every man of average means.



THE "ZOROASTER," A MAIL, PASSENGER, AND CARGO SHIP DRIVEN BY OIL

This ship, which was launched in 1911 for Messrs. Nobel Bros., of St. Petersburg, is driven by a 1000 horse-power Kolomna-Diesel engine, and attains a speed of eleven knots. It is 270 feet long, and has a beam of 33 feet 9 inches.

THE GIGANTIC ENTERPRISE WHICH WILL LINK THE SEABOARDS OF THE UNITED STATES



The Panama Canal, the making of which is proceeding rapidly, will put the final touch to America's splendid geographical situation, and will bring her two extensive ocean borders in direct communication with all parts of the world. With the completion of the canal, the shipping of the United States is expected to show an immense development. This photograph shows the work of erecting the enormous gates at the entrance to the canal.

HALVING A CONTINENT

The Long Fight with Nature for Mankind's Right of Way between Atlantic and Pacific

THE MARRIAGE OF THE TWO GREAT OCEANS

A PRODIGIOUS dream, four centuries old, is being translated into solid fact before the eyes of the civilised world. It is anticipated that in the year 1913 there will be a highway of water for ships through what since the American Continent was first formed has been dry land. Two oceans are to be united, and ships will pass from the Atlantic to the Pacific and from the Pacific to the Atlantic, by climbing, water-borne, through the hills of the isthmus of Panama. The thoughtful traveller may soon take his stand, like "stout Cortes"—

"Silent, upon a peak in Darien;"

but not to see, as the emissary of Spain saw, the two oceans impenetrably barred from each other. From his eyrie he will see the vision of ages realised, and ships with dimensions and power undreamed of by Columbus and Magellan sailing through America—ships that are great floating cities, richer far than the golden argosies which laid the treasures of the New World at the feet of the monarchs of the Old World.

A coincidence worthy of note is associated with the making of the Panama Canal. It was the overthrow of the Mongol dynasty in China that first led to the closing of the overland route to the East revealed by Marco Polo. The Chinese resumed their habits of exclusiveness, and the rapid spread of Mohammedanism, which flowed over a wide area, completed the barring of the way by land. A sea route, therefore, became necessary. Columbus sought China by way of the West, and thought he had found India when he reached the American continent. Da Gama ventured round the Cape, and made his way out across the unknown deeps of ocean to India, and Magellan sailed on and on until he found the Pacific. So this event in history, the finding of a way round Africa to the East, and of a sea highway round America to the East beyond the West, were consequent upon the overthrow of the Mongolian dynasty.

The world has just witnessed the downfall of the Ch'ing dynasty, which succeeded the Mongolian, and that event marks also, appropriately, the opening of a way *through* America. Those sea-paths first charted when China was changing rulers lasted varying periods. Da Gama's route from Europe to the Orient by way of the Cape and Indian Ocean was used from 1497 down to 1869, when the Suez Canal was opened; and Magellan's from the Atlantic to the Pacific, by way of the strait whose name immortalises his feat, from 1521 down to the present day. China forced the Spaniards out to sea, to find a land which Anglo-Saxons were to make their own; it has remained for Chinese and Spaniards to help to carve a pathway for ships through the land, while the science of latter day Britons has enabled the promoters of the scheme so to safeguard the lives and health of the workers engaged in the undertaking that the shadow of death, which for centuries brooded menacing over the isthmus, has ceased to retain its ancient terrors.

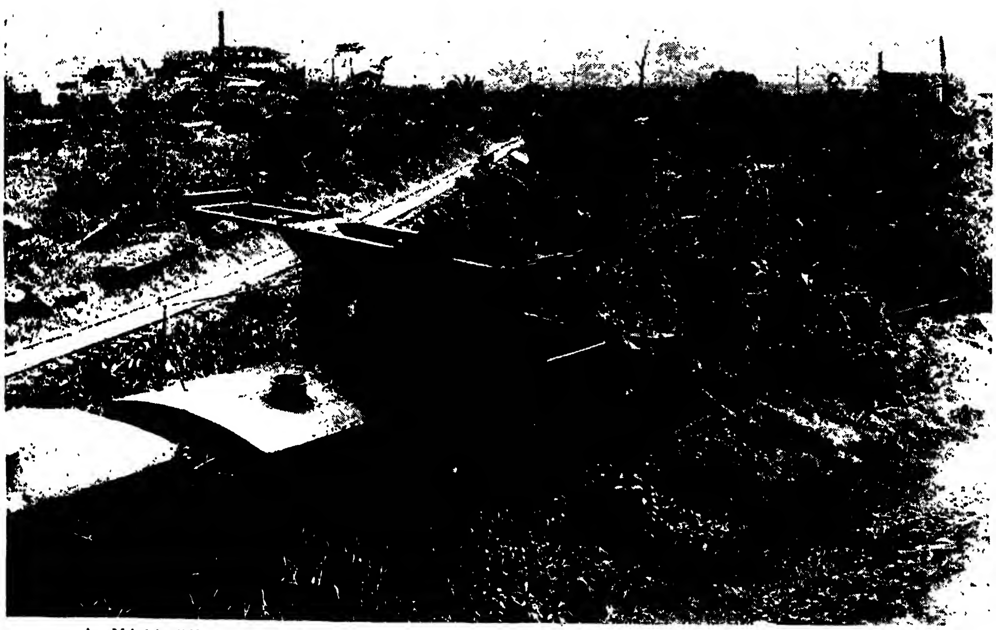
The quest for a way through the continent did not end with Columbus. Vasco Nenuz de Balbao sought the way on foot, and in 1513, from an eminence in the newly-settled Darien, for the first time saw the "Great South Sea" which, eight years later, Magellan was to name the Pacific Ocean. But ten years later still, Charles V. was writing to Cortes, charging him to impress upon all provincial governors the necessity of examining every bay and river mouth which offered a possible solution of the problem; and the tough old hero replied that in his belief it could and would be done, and so render the King of Spain

"master of so many kingdoms that he might call himself lord of the world." The conqueror of Mexico little dreamed that when a way through was eventually found, the dominions of this "lord of the world's" descendants would not include an inch of American soil.

Much time and energy were expended in quest of the non-existent waterway, and by the middle of the sixteenth century Gomara, a far-sighted Spanish writer, was advising Philip II. that "Mountains there are, but likewise there are hands; take but the resolve and it (a canal) shall be cut." And for three and a half centuries afterwards other men were saying much the same thing, though with less emphasis on the "mountains." Many adventurers planned a way through, but William Paterson, the founder of the Bank of England, was the first man really to make an attempt to get beyond the theoretical stage. When he set up his ill-fated Darien colony—a colony calmly settled upon land already belonging to Spain—he included an isthmian canal in his project. The Dutch had a scheme two centuries ago; and the joint kingdoms of Belgium and Holland actually had a concession for the work in the earlier half of last century.

It was not until De Lesseps had made a success of the Suez Canal that the United States began to think of making "an American canal on American soil," and to cause the isthmus to be surveyed with a view to finding the best practicable route. Before anything could result from this, a French naval officer, Lieutenant Lucien Napoleon Bonaparte Wyse, appeared in Colombia as representative of a syndicate, made a rapid superficial survey, and obtained from the Republic a concession by virtue of which a canal was to be constructed and operated by his company. That, so far as Wyse was concerned, began and ended the question of canal-making, except for the fact that he sold his concession to De Lesseps for £400,000.

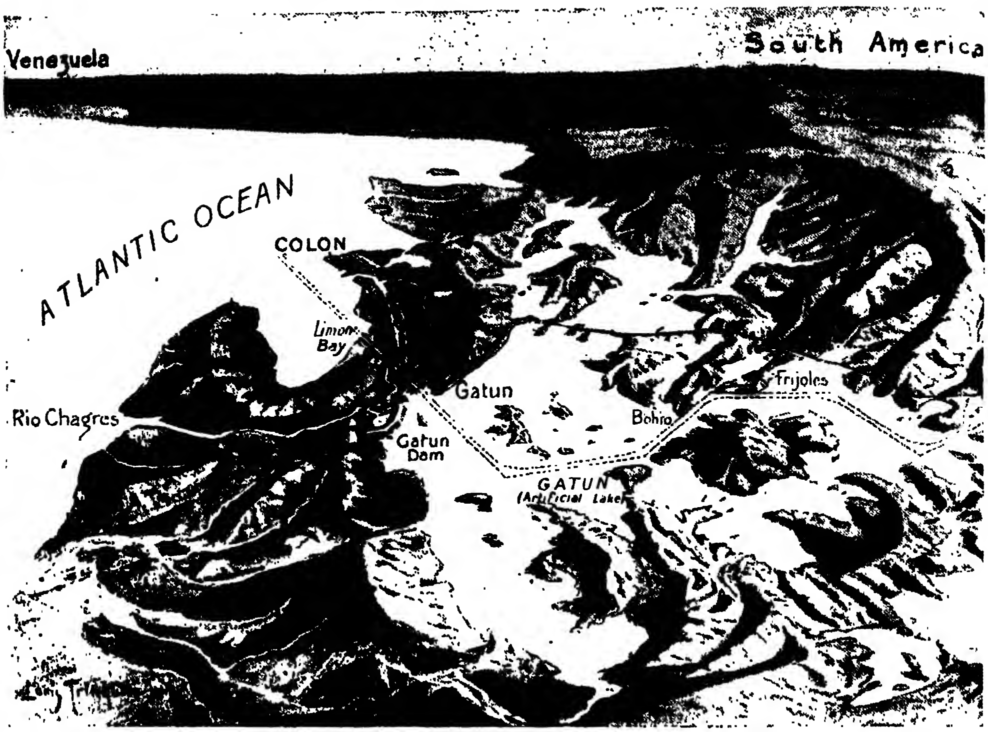
Yet although the canal zone no longer belongs to the Republic which entered into the agreement with Wyse, it is by virtue of that concession that the canal now approaching completion has been built. De Lesseps bought out the Wyse party, and the United States bought the wreck of the De Lesseps undertaking; but it was a new-born republic, the Republic of Panama, from whom they finally acquired the land constituting what is known as the canal zone.



A MASS OF OLD MACHINERY LEFT BY THE ORIGINAL FRENCH EXCAVATORS

BLOWING UP A HILL WITH DYNAMITE

The hill shown in the upper photograph formerly stood in the track of the Panama Canal. The crest of this hill, a mass of solid rock weighing over 500 tons, was removed by the explosion of twenty tons of dynamite, as shown in the lower picture.



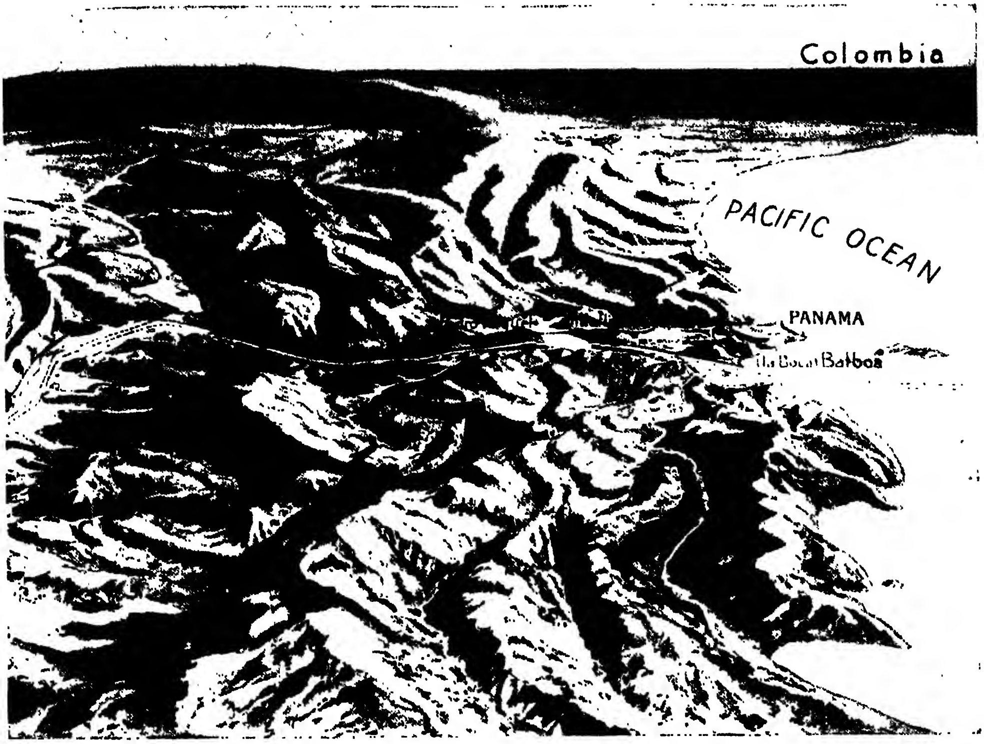
SEVERING TWO CONTINENTS, UNITING TWO OCEANS, AND GIRDLING THE WAIST OF THE

In February, 1881, the first squad of De Lesseps' men arrived at Colon, to begin surveys, the building of hospitals, camps, and so forth. What was called an international commission of engineers had had a brief series of consultations, and had decided upon the route now familiar.

The world was to be given a sea-level canal for £24,000,000, and, before a spadeful of earth was turned, the delegates to the engineering conference were invited by the optimistic De Lesseps to meet him for the opening of the canal in 1888. When that date was reached the company was in a hopeless case. Its proceedings had become a national scandal. Thousands of families had been ruined by its operations; it had shaken the credit of France to its foundations; had shattered Governments, and made the very name of Panama a by-word. Instead of the promised opening of the canal, the hapless shareholders found the company in liquidation, with £70,000,000 of debts; with 120 locomotives, some of which had never been used, rusting in their sheds; with millions of pounds' worth of plant dropping to pieces in the mire and damp; with fleets of tug-boats rotting in the water; and with forty miles of wreckage of machinery of all sorts that had cost millions to buy.

Amazingly impossible consignments were included in the goods sent to the canal. There were vast numbers of snow-shovels, a cargo of hairpins, many grand pianos and 15,000 ornate torches, bought in readiness for the opening ceremony to which De Lesseps had invited the world. A hundred millions sterling had been sunk in the canal. One-third, it was said, had been spent on the canal, one-third had been wasted, and the remaining third stolen. The directors were arrested and placed on trial, with the result that De Lesseps, his son, and others were sentenced to imprisonment. Europe rang with the sorry story of the peculation of directors, of their corruption and bribery of Ministers, of newspapers, and of Government officials; but a later trial secured the acquittal of the former convicts.

A new company, with a capital of less than two-and-a-half millions, was formed less with a hope of carrying the stupendous work to a conclusion than with a desire to preserve such assets as remained. They called to their aid another commission of engineering experts, whose examination led them to report that the conditions were no



WORLD—A PICTURE MAP OF THE PANAMA CANAL ABOUT TO BE COMPLETED BY THE U.S.A.

such as to justify a recommendation that the sea-level canal project should be pursued. The only thing to be done was to aim at a lock canal, the middle reach of which should be 68 feet above mean sea level.

Fate was all this time steadily developing a position favourable to the acquisition of the canal by the United States. The latter had been checked by the French enterprise. De Lesseps brought such prestige from the Suez Canal that it seemed hopeless to compete with a scheme of which he was at the head. But when the French venture began to totter, the idea of "an American canal on American soil" was revived. Again surveyors ran their instruments over the isthmus, avoiding Panama, of course. Perhaps national pride had something to do with the determination to seek a route different from that selected by Europeans, for there was at first no thought of co-operation in the Panama scheme. Indeed, a treaty was concluded between the United States and Nicaragua for the construction and joint ownership of a canal bisecting the isthmus from Lake Nicaragua to the Atlantic.

When this failed to pass the United States Senate, a private company was formed, and really began, in 1889, on the Atlantic side, to dig a Nicaraguan Canal. They were in earnest. They built a railway, they dug their channel three-quarters of a mile inland from Greytown, and had spent nearly a million sterling when bankruptcy, through panics then generally affecting the money market, put an end to their operations. What a private American corporation had failed to effect, the American nation felt compelled to execute. The war with Spain had made the necessity for a canal through the isthmus emphatically pressing, and the matter resolved itself simply into a choice of route. The Nicaraguan scheme, although it involved a canal more than three times as long as that by the Panama route, had enthusiastic support, and every American economist must be devoutly thankful to-day that his cherished hopes of a dozen or so years ago were disappointed. It was estimated that the Nicaraguan Canal could be built in ten years at a cost of rather more than £40,000,000, and this sum, it was thought, would be considerably in excess of that necessary to complete the rival undertaking. Still, the Nicaraguan route had been begun, there was the inviting Lake Nicaragua ready to the engineer's hand,

and a navigable river also available. Admittedly the passage of ships through Panama would be twelve hours as against the thirty-three necessary to clear the Nicaragua Canal; but this would be counterbalanced, it was pointed out, by the fact that ships from New York to ports north of the canal on the Pacific seaboard, as well as from Liverpool and other British ports, would be saved some hundreds of miles by taking the Nicaraguan route, a consideration that cancelled the saving of time offered by the alternative passage. Therefore, taking one consideration with another, Congress was advised to adopt the Nicaraguan route.

This meant a death-blow to any hopes which the new Panama company may have entertained of getting profitably out of their difficulties. They had the sole concession from Colombia, it is true, but it was useless to themselves. The United States refused point blank to come in as part proprietors. The French could not afford opposition to their scheme, so there remained but one course open, and that was to sell out, lock, stock, and barrel. And the United States agreed to buy. Having vowed that the Nicaraguan was the better route, they proved their wisdom by eagerly accepting the opportunity to buy up the other. The Bill sanctioning the construction of the Nicaraguan Canal had actually passed the House of Representatives when this deal took place; but the Bill was stopped before it could be endorsed by the Senate, and in its place an Act was passed enabling the United States to acquire De Lesseps' ill-fated venture. For this latter the shareholders received £8,000,000, and one of the blackest chapters in the history of commercial France was closed.

FIFTEEN HUNDRED LABOUR RECRUITS ARRIVING FROM BARBADOS TO WORK ON THE CANAL

So far negotiations for the land through which the canal was to be run had been conducted with the Colombian Government; but when the latter, having consented to the French company's disposing of its right, came to deal with the United States, it kicked over the traces, so to speak, and negotiations were suspended. A little delay would have sent the United States to the Nicaraguan route, for that alternative remained within the discretion of the President. But then one of the most curious things in modern history happened. The people of Panama broke away from Colombia, and formed themselves into an independent republic, the Republic of Panama. A new Power, of infinitesimal magnitude, had swum into the ken of the world's diplomatists. The new republic repudiated its share of the Colombian national debt, and began de novo, with the canal route as its great realisable asset. One republic had stood between the rest of the world and a pressing reform; another had sprung into being to make the reform possible. The republicans of Panama were very well paid for their action.

The Republic of Panama was born on November 4, 1904, and fourteen days later it signed a treaty with the United States providing facilities for the construction and maintenance of the inter-oceanic canal. They received £2,000,000 down for their complaisance, with the promise of an annual £50,000 after nine years. For this Panama conceded in perpetuity the use of a tract of land five miles wide on each side of the canal route, and, within this zone, exclusive control of police, judiciary, sanitary, and other purposes. They added further territory for subsidiary canals, while, for the defence of the canal, the coastline of the zone

CLEARING A WAY FOR THE PANAMA CANAL

A MONSTER STEAM-NAVVY AT WORK SCOOPING UP IN ONE IRON GRIP A TRUCK-LOAD OF ROCK AND SOIL

and the islands in Panama Bay were also ceded. The cities of Panama and Colon remained under the jurisdiction of the new Republic, but complete control in regard to sanitation and quarantine in both cities was vested in the United States. This latter clause, as we shall see, was one of the most important in the making of the canal.

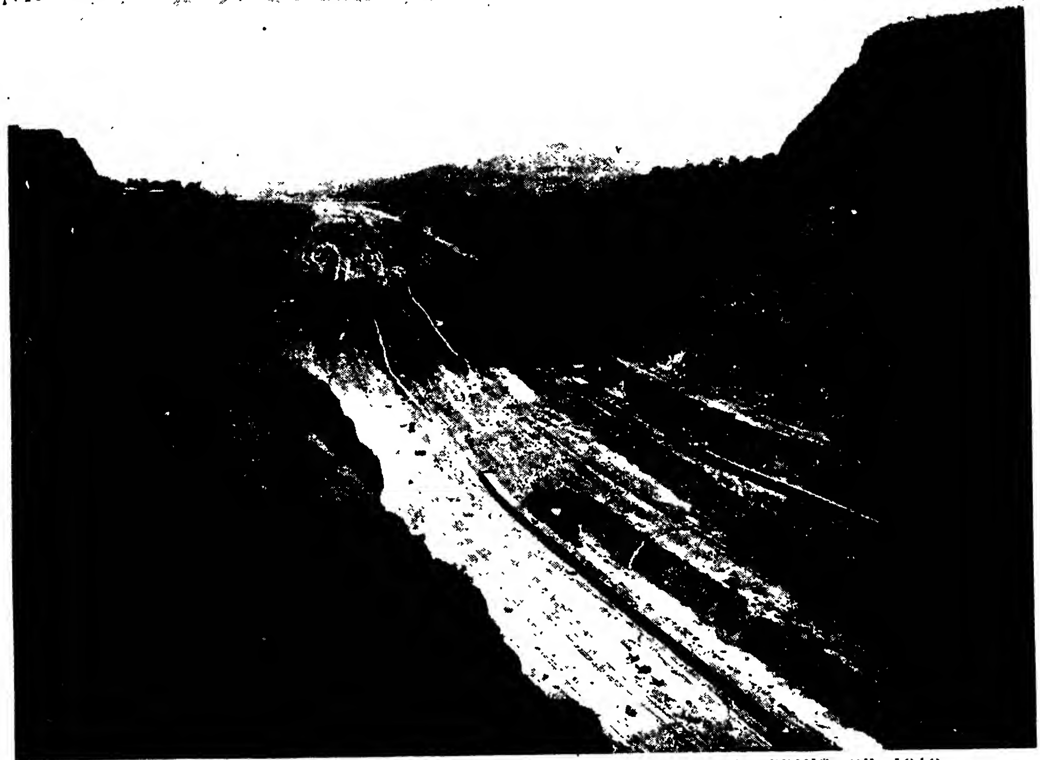
Work was begun by the United States engineers on May 4, 1904, on the understanding that a canal at sea level was to be cut through from Limon Bay, on the Caribbean coast, to the Gulf of Panama, on the Pacific coast. The French engineers, between 1881 and 1904, had excavated 81½ million cubic yards; and it is only fair to state that to-day, after their own experience of the work the American authorities speak in terms of highest appreciation of the character of the labours of the Frenchmen, work done under extreme difficulty, and at a time when the science of sanitation and mechanical art fell far short of the high plane at which they have now arrived. It was early decided that the American Government should itself carry out the undertaking, under the direction of the United States military engineers. That probably was an excellent provision, but the decision that all materials used must be American has added enormously to the cost of the canal.

The enterprise opened with 600 men at work, and this number was rapidly augmented, in order, in the words of Mr Roosevelt, to "make the dirt fly." But the isthmus remained a "white man's grave"—the most unhealthy place, with one exception, on earth. No serious attempt had been made by the French to grapple with the problem. Their workmen had died in thousands. The "Times" recently stated that the undertaking cost, under the old régime, no fewer than 50,000 lives. The Americans soon found that, unless systematic precautions were taken, they would constantly have an army of sick and dying on their hands.

GATUN LAKE, THROUGH WHICH THE CANAL PASSES BY A DEEPENED CHANNEL

A few years earlier it would have been impossible to check the ravages of many of the diseases which assailed the workers. But, as economic causes had prepared the way for the American engineer in Panama, so men like Sir Patrick Manson, Major Ronald Ross, and Col. Sir David Bruce, by their investigations of the fever-carrying mosquito, had made it possible to protect the health of the men called to do the digging. After some little time, in which men were stricken down like flies, the dirt

MAKING THE WORLD'S BIGGEST TRENCHES



THE DEEP CULEBRA CUTTING AS IT APPEARED IN THE SPRING OF 1910

REMOVING A MASS OF EARTH THAT HAS FALLEN INTO A CUTTING

CLEARING AND STRAIGHTENING MOUNTAIN-SIDES THAT SLIP OBSTRUCTIVELY AWAY

One of the greatest difficulties of the construction of the great interoceanic canal has been the instability of the ground through which the channel is cut

ceased to fly. The American Senate was staggered, in December, 1905, to hear that, although there were 17,000 men engaged on the Panama Canal, not a spadeful of earth was being turned. The United States had promised a complete sanitary reform for the isthmus, but, instead of giving effect to their promise, they had bustled into the digging, and the result was fatal. Men were dying or sickening, and scores, including officials, were fleeing the district rather than face the terrors of yellow and malarial fevers, typhoid, dysentery, and other ills. Late in the day it was recognised that the cart had been put before the horse, and the biggest engineering undertaking in the world came to an absolute standstill, while a great campaign for the preservation of health was carried out. Col. Dr. Gorgas, who, by putting into practice the teaching of British experts in tropical diseases, had banished yellow fever from Cuba, was called in, and carried out a similar scheme right across the isthmus.

The whole force of the labour army was turned on to the work of laying pavements, draining or filling up swamps, cutting away thickets, banishing garbage and rubbish, obliterating the breeding places of the deadly mosquito. Every house was sealed up and fumigated, sanitary arrangements were perfected in every town and village, and, as Sir Harry Johnston has since shown, the health and climate problems of the canal zone became transformed into a mere question of degrees of comfort and hygiene in daily life. Food, which had been unsatisfactory when supplied by the natives, was brought direct from the United States. Alcoholic drink was absolutely forbidden, except at Colon and Panama. Gambling, too, was prohibited. The isthmus, from a sink of crime, debauchery, and pestilence, as it had formerly been, has now become a model settlement, into which men have taken their wives and families with perfect safety. It is a striking thought that the two Poles have been discovered by teetotal exploring parties, and that the two outstanding engineering feats of modern times, the Florida sea-going railway and the Panama Canal, have been constructed by men practising the same abstinence.

LOADING BUCKETS FROM THE CONCRETE MIXING PLANT AT GATUN

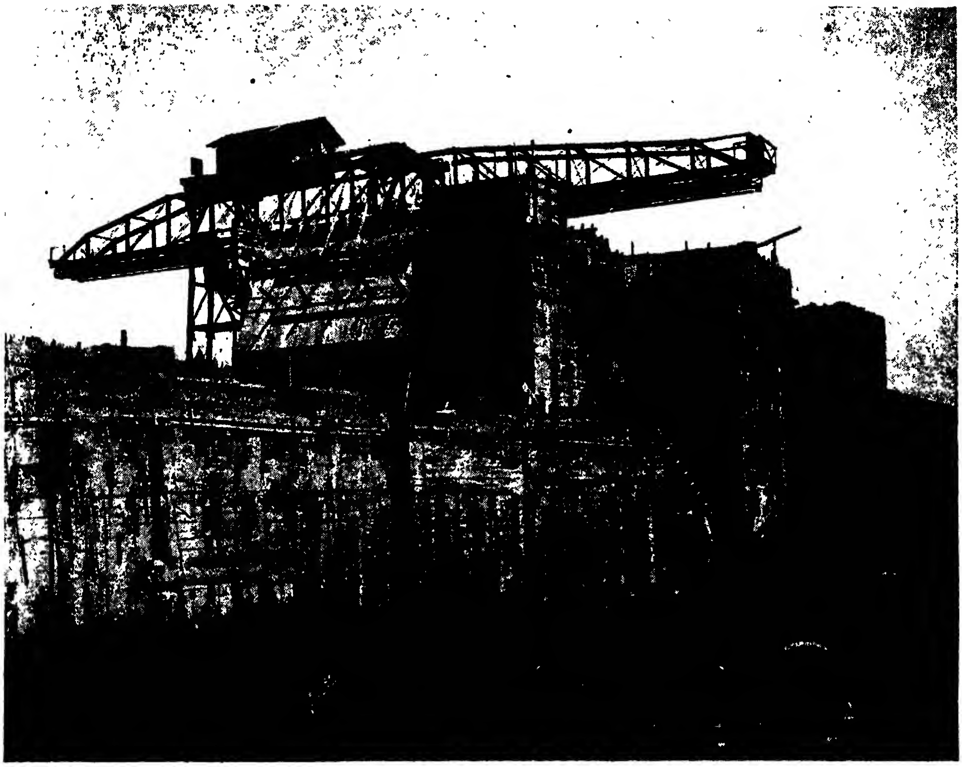
Having rectified their initial error as to health precautions, the United States had a great engineering blunder to repair. They began, as we have seen, on a sea-level canal. Not until two years had passed was this found impossible. Then suddenly plans were changed, and a lock

canal decided upon. Happily the work done served equally well for either purpose, so that no money was. wasted by the alteration. But the estimates as to price were very wide of the mark. Instead of 25 millions, which a lock canal was to cost, as against the estimated £53,000,000 for a sea-level canal, the less ambitious scheme, that of a canal comprising a series of locks, will have cost the United States between 75 millions and 80 millions before the last account has been settled. Even today we are told that, should the present canal prove inadequate, the original plan would be reverted to, and a sea-level canal constructed. Such courage is notable, of course, but the errors committed cannot but shake public faith in the financial estimates of men responsible for advising States or public bodies.

Be that as it may, it is a lock canal through which ships will first pass across the continent of America. The canal will be 46 miles in length from shore to shore, but its channel will be continued some little distance out to sea on the Atlantic side, and slightly farther into the Gulf of Panama. The difficulties encountered have been immense. For 39 miles of its course the canal runs through hilly country. A track has had to be blasted through these hills, and enormous masses of soil and rock removed. Moreover, the River Chagres which runs into the Atlantic, had to be dammed and harnessed to form a vast artificial lake. This constitutes the middle reach of the canal, which is now to be 85 feet above mean sea-level. The construction of the dam for this lake and the locks by which vessels climb up into it represents the biggest engineering performance of the kind ever achieved in the history of the world. Here, then, is the plan of the entire canal.

A ship proceeding from the Atlantic to the Pacific enters a deep-water channel in Limon Bay, 500 feet wide and some six miles long. This brings us to the great Gatun dam. At this point the ship must simply mount a staircase. It does so by means of three locks, each 1000 feet in length, 110 feet in width, and 41·3 feet deep at the sills. These locks, it should be explained, are in duplicate, so that two vessels may perform the climb simultaneously. Each lock raises the vessel 28·3

A STEAM-SHOVEL LOADING ROCK ON TO A RAILWAY TRUCK



THE MASSIVE EAST WALL OF THE LOCKS AT PEDRO MIGUEL

feet, so that, on quitting the third, the ship enters a waterway 85 feet up in the air, so to speak. The third lock gives access to this artificial lake, the River Chagres having become practically a miniature inland sea 23½ miles in length, with a navigable channel ranging from 500 feet to 1000 feet in width, and with a total area of 220 square miles. The conversion of this river into a lake is one of the triumphs of the scheme. The Chagres in time of flood varies greatly in height, a circumstance which, it is thought, would have been inimical to the sea-level scheme. But under the existing arrangement the margin allowed for the reception of excess water effectually overpasses the difficulty.

Fast steaming is possible throughout the length of the lake. At the end of the lake the ship passes, at Bas Obispo, into what is known as the Cubebra cut, the section where, owing to the height of the land, the greatest amount of excavation has had to be carried out. Here a channel, 300 feet wide and rather more than eight miles in length, leads, by the same water-level as the lake, to Pedro Miguel, where twin locks make a drop of 30 feet into a lake just short of a mile in length. This leads to Miraflores, where two twin locks, each with a drop of 27·5 feet, have to be negotiated. This brings the vessel down to tide-level, and she then steams another eight miles or so and reaches the Pacific.

That, briefly expressed, is the design of the Panama Canal, but it conveys no idea, of course, of the immensity of the operations that have brought the scheme into being. The Gatun dam is a veritable engineering monument. It is 7600 feet in length at the top, 2600 feet thick at the base, 135 feet high, and many million cubic yards of material have gone to its making. The Gatun locks, the largest and most powerful ever made, contain well over 2,000,000 cubic yards of masonry, each yard costing 28s., in spite of the fact that all the material required, except the cement, has been obtained on the spot.

The mass of material excavated is, of course, prodigious, amounting roughly to 40 million cubic yards in the course of a single year, though not for each year. During 1911, 17 million cubic yards were taken out of the Cubebra cut alone; but of this, 5 million cubic yards was due to

landslides. The unstable condition of the strata has, indeed, been a serious handicap to the engineers. After work was well advanced for the seaward locks on the Pacific side, it was found that the site first chosen, at La Boca, was quite unsuitable, and the work had to be redone at Miraflores, three miles farther inland. Then, in spite of all the investigations on the site of the great Gatun dam, it was found necessary to drive a row of triple sheet piling right across the Chagres valley in which the dam is formed.

The Colossal Task of an Army of Men and Monster Machines

Old landslides, which the French were thought to have mastered, came into evidence again at more than one place; and it is not impossible that more may yet be heard of the rotten red clay in which these disturbances have originated.

But all the difficulties that have arisen have been courageously and skilfully met, and the end of the task is now in sight. Everything that ingenuity could suggest and inexhaustible funds procure has been lavishly employed upon the work. With a staff of men varying from 35,000 to 40,000 has been associated possibly the finest plant of machinery ever got together. In addition to the great fleet of dredgers at each end, there have been 100 steam shovels constantly at work, shovels ranging from 45 to 90 tons each in weight, some of them taking out as much as 3100 cubic yards in the course of the day. Each shovel has been preceded by patent boring appliances to prepare the way for the blasting charge, and the steam navvies have either scooped away from below at the sides of the cutting or have been arranged on terraces, stepped back one above another.

The Removal of Tons of Soil from Cutting to Dumping Ground

Considerable ingenuity has been displayed in the disposal of material excavated. In order to remove this from the cutting, a constant relaying of railway lines has been necessary; and for this purpose the engineers have had the assistance of a special track-shifting appliance, which takes up the coupled rails in sections and relays them in the position desired. Care has been taken to have each dumping-ground as near as possible to the cutting; but, even so, some of the dumps have involved a journey of four or five miles each way for the soil-train. Much of the material excavated has been used for the works, but where this has not been possible large depressed areas have been filled in with the surplus material. To load the dump-trucks has been an easy matter, seeing that with each cut of the steam shovel from three to five cubic yards of soil or broken rock are removed. The emptying of the trucks has, however, necessitated the use of what is called a steam plough, which in ten minutes clears twenty cars, each containing from 20 to 40 tons of material.

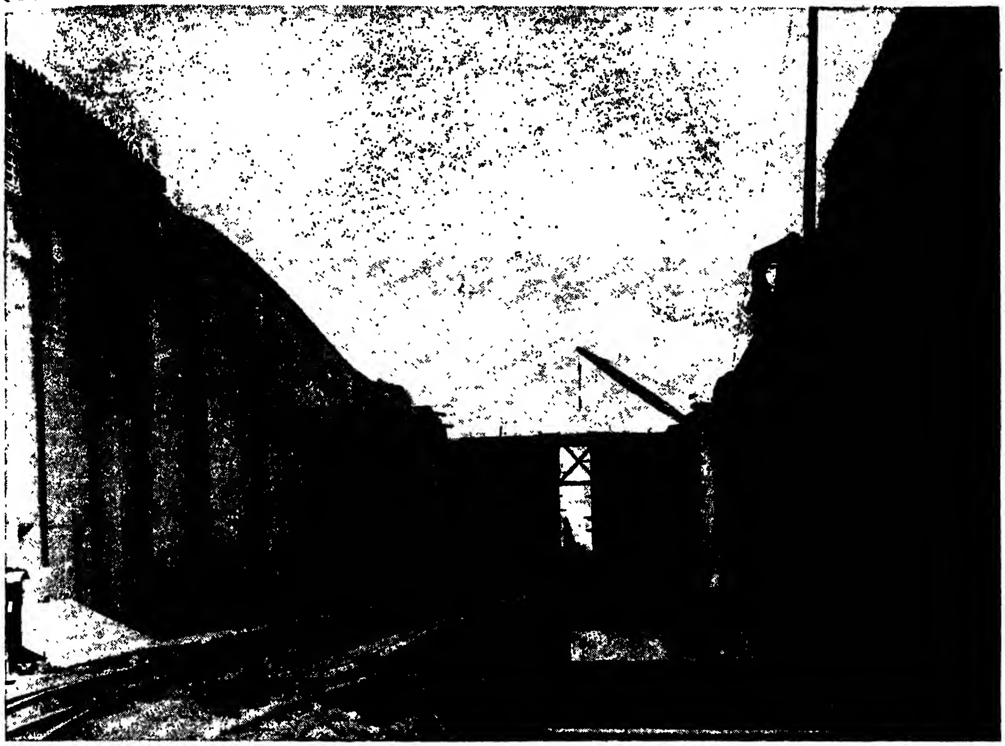
The equipment for the canal itself is as complete as the plant wherewith it has been built. The lock-gates are to be actuated by electricity, and are the largest structures of the kind in existence. Some have been built in American machine-shops before dispatch, and some on the spot. The former, after completion, were taken to pieces and transported to Panama in sections. For their erection bridges are built across the locks, traversed by locomotive cranes which make it a matter of small difficulty to build the component parts into position. A complete electric plant is being installed for the haulage of vessels through the locks.

The Huge Chain-Brake That will Bring a Liner Quickly to Rest

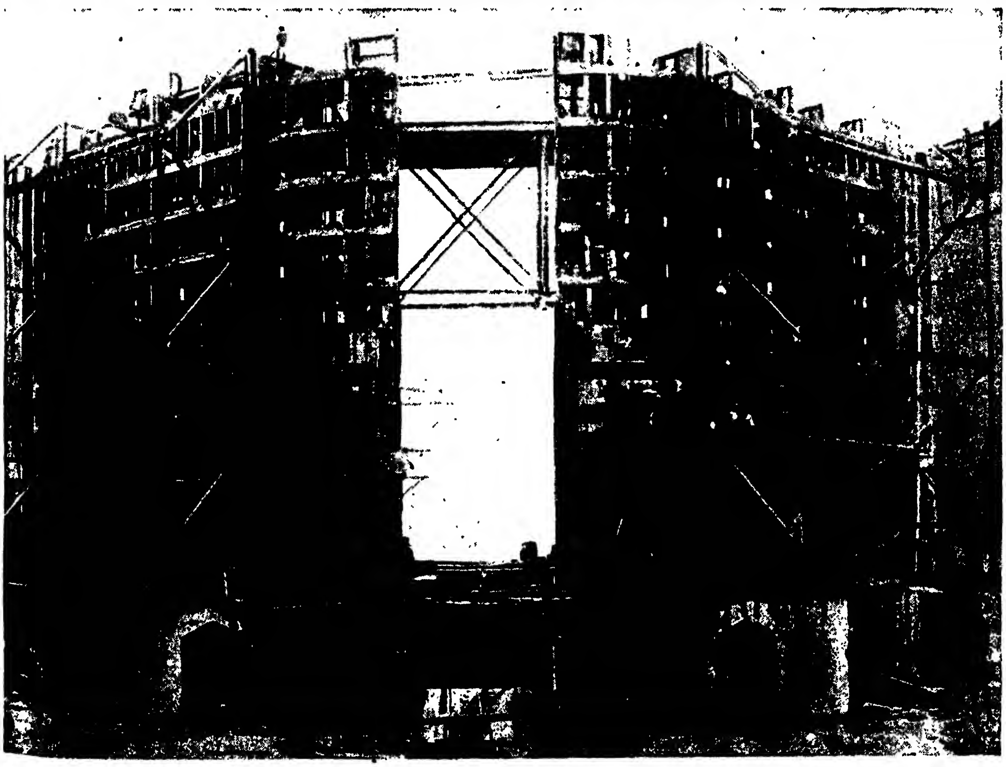
Here arises an interesting point which might not naturally occur to the lay mind. It is easy enough to get a huge vessel moving, given the requisite power, but how is the craft to be stopped? The momentum of a sea leviathan is enormous. What is to prevent the vessel, once it starts, from crashing into the gates of the lock? A highly ingenious scheme is being put into operation. In each lock what is known as a fender chain, a huge steel cable, is installed. It lies at the bottom of the lock until the time for action. Then it is raised, by hydraulic pressure, evenly from both sides of the lock. The moving vessel gently strikes this chain, which slowly yields to pressure, paying out, under the control of hydraulic cylinders, as the vessel advances towards the gates. The chain is fixed at about 75 feet from the gates; and careful calculation shows that it will bring a vessel of 10,000 tons moving at four knots, or a 50,000-ton vessel at two knots, to rest within 70 feet.

The whole effect of the work carried out goes to show that this canal could not have been built earlier. With the mountainous backbone of the isthmus to break through, with a treacherous river to combat, with shifting soils to fix, with engineering requirements of unparalleled magnitude, with work carried on in a climate that embraces

GIANT LOCKS OF THE PANAMA CANAL



THE INTERIOR OF ONE OF THE HUGE LOCKS AT GATUN



A CLOSE VIEW OF ONE OF THE LOCK GATES APPROACHING COMPLETION

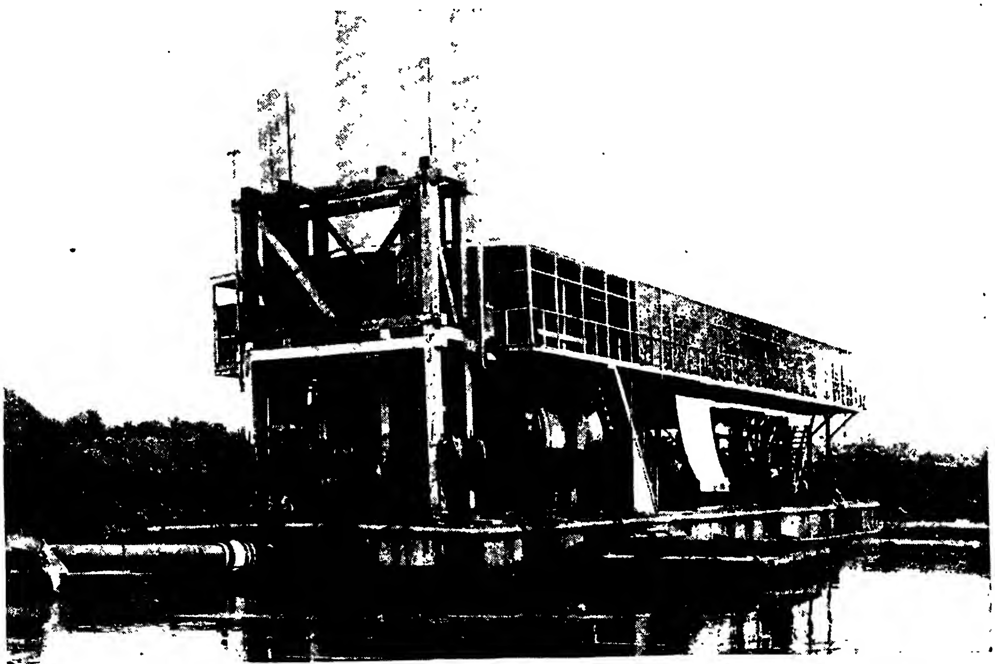
SHIPS MAKING, AFTER FOUR HUNDRED YEARS, THE MIDDLE PASSAGE OF THE NEW WORLD

AN IMAGINATIVE SKETCH OF THE PASSAGE OF THE PANAMA CANAL, WHICH IS EXPECTED TO BE OPENED FOR THE FOUR HUNDREDTH ANNIVERSARY OF THE FINDING OF THE PACIFIC OCEAN

a rainy season of from eight to nine months out of the year, in the home of fever and pestilence, the hour and the men had not arrived even when De Lesseps put his hand to the task. The machinery necessary did not exist; the discoveries of Manson and Ross and Bruce had not been made. The work was to be done in the twentieth century.

In the matter of life preservation we have advanced as far in knowledge, between the beginning of the work by the French and the present time, as engineers had advanced in their craft between William Paterson's era and that of De Lesseps. Even had all the knowledge been available, this canal could not have been cut unless a nation had been ready to finance it. The work must have broken any private organisation in existence. The American promoters undertook a lock canal because they thought it would cost from 25 to 28 millions as against the 53 millions necessary for a sea-level canal. The lock canal, when finished, will have necessitated the outlay, all told, of between 80 and 100 millions. The United States are the only nation that could, or, at any rate, would, have afforded such a sum for a single scheme.

Of course, they will be richly rewarded. They will have what amounts to a continuous seaboard from the State of Washington to Maine, and their naval fleet will be rendered at least twice as effective. But it is the peaceful victories of commerce rather than the exigencies of war which are mainly considered. The Panama Canal will mean a saving of fully 8000 miles between the two coast-lines. Other distances, too, will be greatly shortened. From Liverpool the journey to Pacific ports north of the canal will be lessened by over 6000 miles, and by between 2000 and 3000 to Pacific ports south of the canal. Asiatic ports, too, will be brought much nearer to New York; while both Sydney and Wellington will be 2500 miles nearer to New York than to Liverpool.



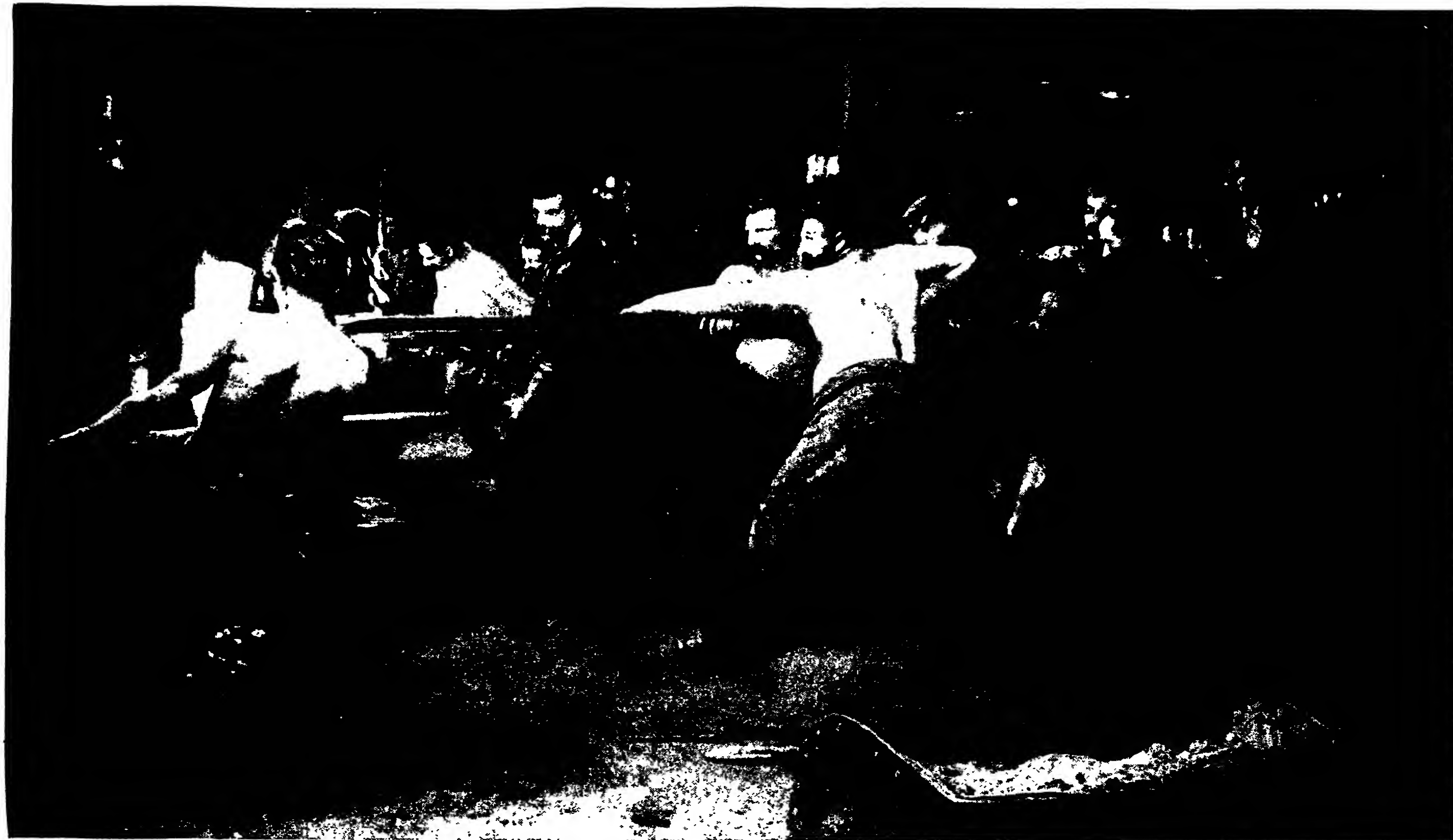
THE SAND-DREDGER USED IN MAKING A DEEP CHANNEL IN THE GATUN LAKE

In conclusion, it is of interest to contrast the figures of the Suez and Panama Canals:

SUEZ		PANAMA	
Length	99 miles	Length	46 miles
Width	121 feet	Width	300 to 500 feet
Depth	28 feet	Depth	41 feet

The Suez Canal in its first form cost £10,000,000, but alterations and extensions raised the sum to £24,000,000. The shares in this canal held by the British Government, costing four million pounds, now produce over a million a year dividend, and are worth to-day nearly £38,000,000, or almost half the cost of the Panama Canal.

THE GRIM HUMAN LABOUR THAT MUST BE USED TO MASTER THE MASTER-METAL



The work of the "Puddlers," which no machinery can supersede, is here represented in a copy of the painting by J. Rixens, in the Musée de la Ville, Paris.

TRADE'S IRON SCEPTRE

Extraordinary Growth of the World's Iron Trade, and the United Kingdom's Decreasing Share in it

WHY THE LEAD HAS PASSED TO AMERICA

We have already observed that the middle of the eighteenth century marked a turning-point in British industry and commerce. Before that time, the United Kingdom was in the main an exporter of raw materials and an importer of manufactured articles. Since that time the position has been reversed, and Britain has become the chief exporter of manufactured articles and the hungriest importer of the raw materials of industry.

The change is most strikingly illustrated by the great iron industry. The statistics of the eighteenth century are not very full, but there is no doubt whatever that our imports of iron were then enormously greater than our exports. According to Scrivenor's "History of the Iron Trade," in the years 1729-35 we imported about 25,000 tons of iron on the average per annum, whereas we exported only about one-fifth as much. Hewitt, in his "Iron Statistics," puts the total produce of iron by England in 1740 at only 17,350 tons, whereas Europe as a whole at that time produced 100,000 tons. Metallurgy was much better understood on the Continent of Europe than here, and we find that foreign workmen had to be imported into England to make cannon. Scandinavia and Russia were large exporters of iron to England, and by the middle of the eighteenth century British iron production, instead of progressing, had begun to decline.

There was a good reason for this. The smelting of iron depended, of course, upon fuel, as it now depends, and the fuel of the ironmaster of that day was, of course, charcoal. The North of Europe with its enormous forests had a tremendous natural advantage in point of fuel, and the United Kingdom vainly destroyed her fine woodlands in the South in an attempt to sustain an iron industry. The influence of fuel on iron manufactures is shown by the fact, commented on by Jevons, that in the course of the seventeenth century the English iron trade migrated in part to Ireland, in spite of the fact that Ireland had no iron ore; the ore, that is, was taken to the fuel. So voraciously did iron eat up British timber that we find Elizabeth making laws to endeavour to save it for the special purpose of the "wooden walls of England." To-day, most unhappily, England is the least wooded country in Europe, for neither private nor public endeavour has been sufficiently exerted in afforestation.

It is clear, then, that if some new factor had not arisen to save the situation, the British iron trade would have died an unnatural death, and destroyed itself in destroying British timber. The new factor arose, however. As early as 1621 Dud Dudley succeeded in smelting iron with coal. His process is not precisely known, but he succeeded in making iron at a cheaper price than charcoal iron. Dud Dudley shared the too common fate of industrial pioneers—he died, in 1684, a ruined man. Cromwell frowned on him as a Royalist, and he found it impossible to contend against political trouble and the attacks of unprogressive rivals. At a later date we find a Staffordshire historian speaking of "the last effort in this country to smelt iron ore with pit coal."

Early in the eighteenth century Abraham Darby, with the aid of skilled Dutchmen, started the Coalbrookdale ironworks, in Shropshire, and in 1713 he is said to have succeeded in using coke in the blast-furnace. The new process was of slow development; and it is not even certain that the Coalbrookdale works used coal instead of wood fuel before 1735, in the time of Abraham Darby the younger. By 1750, however, the works were exceedingly successful, and

in 1756 it is recorded that they were producing twenty tons of iron per week at a good profit, using coke for fuel. From this time onwards the trade made rapid growth, and from this time Britain's industrial greatness began. In 1788 England produced 68,000 tons of iron, and of these as many as 48,000 tons were produced from coke and only 20,000 from charcoal.

The call for fuel made it necessary to work British coal as it had never been worked before. The imperative need to pump water out of our mines, in order to get at the coal, led to the invention of the steam-engine. James Watt's patent was taken out in 1769. The needs of the collieries gave us also the railway, and George Stephenson, the colliery engineman, gave us the locomotive. Hand in hand, coal and iron advanced together, the iron utterly dependent on the coal; and Britain, which had so recently possessed dying and struggling industries, became the greatest workshop of the world. *To-day we are removed but five generations from the turning-point in British trade.* Nothing is more difficult than for a nation to realise such facts as these. The course of two generations is sufficient to make a great change such as we have described appear a commonplace—a matter of so little moment as to take no place, however modest, in history as taught in schools.

When we learned how to make use of the great gift of coal, we found ourselves in an exceptionally favourable position with regard to any industry, and particularly so with regard to the iron trade. The United Kingdom has enormous supplies of coal which can be easily worked, and Nature also favoured her with fine supplies of iron ore. Further, both the coal and the ore are placed near the sea, and the coal and ore are often found in close proximity. It was almost as though Britain was designed to be a natural iron workshop.

For a long time our position was not merely extraordinary, but unique. Germany had plenty of coal and plenty of ore, although not so favourably situated as the supplies of the United Kingdom, but Germany was still a geographical expression, torn by internal dissensions, with Customs barriers between her many States, and subject to repeated invasion. Industrial and commercial expansion, which had been stayed for centuries, was to be denied her until Germany found unity in 1870, and secured peace within her borders.

The United States, then as now the greatest iron and coal country in the world, had an insignficant population, and her natural wealth lay dormant, while British advantages were being exploited. The United Kingdom was thus for many years free from serious competition, and, using her power upon the world's materials, she made rapid strides in the nineteenth century in her new rôle of manufacturer, building up unparalleled industries and a world-wide commerce. Not until twenty or twenty-five years ago were the United States and Germany able to get into the running. *As recently as 1885 as much pig-iron was produced in the United Kingdom as in America and Germany put together.* From 1885 onwards, however, the relative position rapidly changed, and Germany and America began to make the same rapid strides as the United Kingdom made at an earlier period. From what has been written, this will be seen to have been of the category of things inevitable.

A successful iron trade depends upon the command of cheap fuel, cheap ore, and cheap flux; and it is not surprising that at one time it appeared to many British observers that Providence had ordained the proximity of these three things in British soil. The coal and the iron and the limestone had not to be hauled together at great expense for freightage; they were found side by side, sometimes in company with useful materials for the building of furnaces. Further, the happy assembling of the essentials of the iron trade was always within a hundred miles of tide-water, and sometimes actually adjacent to it, so that Nature had not only brought the materials together in these islands, but had provided the means of marketing the product cheaply.

We need not be surprised, then, if fifty years ago the United Kingdom exported out of her surplus produce as much iron as was produced by all the rest of the world put together. The other great iron giants lay dormant, or were just beginning to arouse themselves from slumber. In 1862 the production of iron in the world was roundly as follows.

THE WORLD'S IRON PRODUCTION—1862

Approximate Figures.

Country	Tons
Britain	3,900,000
France	1,000,000
United States	700,000
Germany	500,000
All other countries (say)	1,400,000
All the world	7,500,000

It is to be observed, however, and the observation is of importance, that it could not be claimed that the British iron was of the best in quality. On the contrary, the British production was largely composed of inferior metal which could not be used for steel-making. It was a success more of quantity than of quality. In the fifty years that have elapsed far-reaching changes have occurred. For the first half of that time, Britain held the lead; in the second half she has been outstripped by both the United States and Germany.

The world's iron progress can be seen at a glance by the table on this page, which shows the iron output of all the world, and of the chief iron countries, of which Britain, America, and Germany, are the most important. When it is remembered that this table covers a period of only forty years, we are again reminded how rapidly the world of trade moves, and how necessary it is to move rapidly with it. At the beginning of the forty-years, the United Kingdom produced, it will be seen, rather more than half of the iron produced by all the world. At the end of the forty years the United Kingdom produced little more than one-seventh of the world's iron.

These facts demand our earnest consideration. It was to be expected, and, indeed, was expected by intelligent and well-informed men, that the United Kingdom could not hold the lead in iron production. Writing in 1865, five years before the first date given in the table on this page, the late Professor Stanley Jevons pointed out that "it was impossible there should be two opinions as to the future seat of the iron trade. The abundance and purity of both fuel and ore in the United States, with the commercial enterprise of American manufacturers, put the question beyond doubt."

It has been said that prophecy is the most gratuitous form of error, but we see how clearly Jevons's prophecy has been fulfilled. It was based, of course, not on wild imaginings, but on a knowledge of the true economic basis of industry. He realised that the possession of the best coal supplies in the world was bound to give America pre-eminence in iron manufacture as soon as that country was able properly to work her resources. When Jevons wrote the words quoted, the United States produced less than one million tons of pig-iron; in 1910 she produced twenty-seven times as much.

And what of Germany? Jevons was unable to foresee the wonderful progress of the German Empire, not because his economics were ill-founded, but because the world did not then know the extent of the German coal resources. If Jevons had known that Germany had coal resources greater even than those of the United Kingdom, he could have predicted for her, with as much certainty as for the United States, a brilliant industrial future.

THE WORLD'S OUTPUT OF PIG-IRON FOR FORTY YEARS—1870-1910

In Millions of Tons

Year	World	U.K.	U.S.A.	Germany	France	Belgium	Russia
1870..	11·6	6·0	1·7	1·1	0·9	0·6	0·4
1875..	13·7	6·4	2·0	2·0	1·4	0·5	0·5
1880..	18·2	7·7	3·8	2·7	1·7	0·6	0·4
1885..	19·5	7·4	4·0	3·6	1·6	0·7	0·5
1890..	27·5	7·9	9·2	4·6	1·9	0·8	0·9
1895..	29·0	7·7	9·4	5·4	2·0	0·8	1·4
1900..	40·5	9·0	13·8	8·4	2·7	1·0	2·8
1905..	53·5	9·6	23·0	10·7	3·0	1·3	2·7
1906..	58·5	10·2	25·3	12·1	3·3	1·4	2·6
1907..	60·2	10·1	25·8	12·7	3·5	1·4	2·7
1908..	48·2	9·1	15·9	11·6	2·3	1·3	2·7
1909..	60·0	9·5	25·8	12·4	3·6	1·6	2·8
1910..	65·5	10·2	27·3	14·6	4·0	1·8	3·0
Increase in 40 years, 1870–1910 ..	53·9	4·2	25·6	13·5	3·1	1·2	2·6
Increase in 30 years, 1880–1910 ..	47·3	2·5	23·5	11·9	2·3	1·2	2·6
Increase in 20 years, 1890–1910 ..	38·0	2·3	18·1	10·0	2·1	1·0	2·1
Increase in 10 years, 1900–1910 ..	25·0	1·2	13·5	6·2	1·3	0·8	0·2

Developing her coal at last in peace and security, Germany has built up an iron and steel industry which has far surpassed our own in dimensions, and which is gaining upon British production year by year. In this she has been aided by the fortunate discovery by an Englishman, Sidney Thomas, of the means of utilising phosphoric iron ores, a discovery which made available for industry the enormous supplies of ore of this kind which Germany fortunately possesses.

We see, then, that the chief feature in the development of the world's iron trade in the last twenty-five years has been the natural development of America and Germany in a trade which they, like the United Kingdom, are naturally fitted to carry on. We see also that since the American and German development has rapidly proceeded, the dimensions of the British iron trade have grown but slowly, and that in the last ten years they have remained almost stationary.

While, as we have said, it was naturally to be expected that America and Germany, furnished as they are with the means of a successful iron and steel trade, would not fail, in view of the intelligence of their peoples, to attain a great measure of success, the almost stationary output of the United Kingdom in the last ten years has certainly been surprising. It will be seen that in 1900-1910 the increase in British pig-iron production was only 1,200,000 tons. A rather greater actual increase was made even by France, a country which, of course, has not the natural advantages in respect of the iron trade of either Britain, America, or Germany.

It certainly appears that there has been a comparative falling off in British relative efficiency; and this conclusion is supported by the facts as to steel which are given in the very important comparative table on this page.

In 1870, the first year shown in this statement, the steel industry was in its infancy, so that almost the entire lifetime of the trade is put before the reader. It will be seen that in regard to steel we have been outdistanced even more swiftly than in regard to iron, and that in the last ten years the increase in our steel output has been not only smaller than that of France, but of Belgium also. In 1870 the British steel output was almost as great as that of the rest of the world. As recently as 1885 it was greater than that of the United States; it is now but about one-tenth of the world's output.

Looking at all the circumstances of the case, it is to be feared that British ironmasters have scarcely kept themselves on terms with their rivals, either in point of industrial science or of commercial organisation. As to the former, it has fortunately to be recorded that in recent years there has been a great overhauling of British iron and

THE WORLD'S OUTPUT OF STEEL FOR FORTY YEARS—1870 1910

In Millions of Tons

Year	World	U.K.	U.S.A.	Germany	France	Belgium	Russia
1870..	0·7	0·3	0·1	0·2	0·1	—	—
1875..	1·7	0·7	0·4	0·3	0·3	—	-
1880..	4·2	1·3	1·3	0·6	0·4	0·1	0·3
1885..	6 0	2·0	1·7	0·9	0·6	0·2	0·2
1890..	12·2	3·6	4·2	2·2	0·7	0·2	0·4
1895..	16·5	3·0	6·1	3·9	0·9	0·4	0·9
1900..	27·5	4·9	10·2	6·3	1·5	0·6	0·2
1905..	44 5	5·8	20·2	9·9	2·2	1·2	2·7
1906..	50·5	6·5	23·4	11·0	2·4	1·4	2·6
1907..	52·0	6·5	23·4	11·9	2·7	1·5	2·5
1908..	40·5	5·3	14·0	11·0	2·7	1·2	2·6
1909..	53·2	5·9	24·0	11·9	3·0	1·6	2·7
1910..	58·0	6·0	26·1	13·5	3·5	1·8	2·8
Increase in 40 years, 1870–1910 ..	57·3	5·7	26·0	13·3	3·4	1·8	2·8
Increase in 30 years, 1880–1910 ..	53·8	1·7	24·8	12·9	3·1	1 7	2·5
Increase in 20 years, 1890–1910 ..	45·8	2·4	21·9	11·3	2·8	1·6	2·4
Increase in 10 years, 1900–10	30·5	1·1	15·9	7·2	2·0	1·2	0·6

steel plants, and that they are now at a much higher degree of efficiency than ever before. Nevertheless, Britain in recent years has been following on the technical side of the trade where once she led; and modern blast-furnace practice, for example, owes more to foreign development than to British invention.

How the Iron Industry of Great Britain is Handicapped by High Railway Rates

On the commercial side, there are a number of important considerations, and the chief of these is the railway question.

It will be realised that the iron industry is peculiarly one which is affected by railway rates. A big modern blast-furnace swallows up something like 5500 tons of material in a week, and produces from it, say, 1500 tons of pig-iron and 1500 to 2000 tons of slag. The materials—the coke, ore, and limestone—and the products—the pig-iron and the slag—are things costly of transport; and much depends, therefore, upon whether they have to be taken short or long distances, and at what sort of rates their carriage can be secured. That is why it is difficult to carry on a successful iron business with imported materials. It is all-important to assemble the materials cheaply.

It will be gathered from what has been said already that the United Kingdom is fortunate in having her home supplies of ore near her coal, and that, further, she has native limestone for flux within easy access. Moreover, she is able to bring imported ore from Spain or elsewhere by cheap sea-carriage to ports which are very near to her coal. For the purpose of blast-furnaces, foreign ore which can be got at cheaply is better than native ore which entails heavy transport charges. When we turn to Germany and to America, we do not find that these countries have superior advantages in respect of ore. Germany has more ore of her own than we have, but that ore is so far from her coalfields that there is a long haul to the furnace. For example, ores from Luxembourg are taken to blast-furnaces on the Ruhr coalfield.

American Transit Charges for the Materials and Products of Manufacture One-third of Ours

Turning to the United States, we find some districts which, like our own Cleveland, have iron, coal, and limestone in close proximity. On the other hand, ores have to be brought from the Lake Superior iron-mines to Pittsburg, a distance of one thousand miles. To take ore from Lake Superior to Pittsburg is more costly than to bring it from Spain to a British port.

It appears that, although the United Kingdom is a very small country, with excellent ports, and although no part of our islands is more than about one hundred miles from tide-water, our natural advantages are not fully availed of by our manufacturers, because of our relatively high railway rates, as compared with either the United States or Germany. According to Mr. J. Stephen Jeans, American railway rates per ton-mile are from one-half to one-third of their general level in the United Kingdom.

Comparing the rates for iron products from the Staffordshire district to some of the leading centres of British production, the average railway rate is found to be about one penny farthing to three-halfpence per ton-mile. In the United States it is about a farthing to a halfpenny per ton-mile, and in Germany it is from a halfpenny to three-farthings. Mr. Jeans says that the cheapest rate at which Staffordshire iron can reach a port is about eight shillings a ton to Liverpool, whereas the American iron manufacturer can send material of the same description from Pittsburg to New York, a distance of 460 miles, for from 6s. 6d. to 8s. The German, again, can send finished iron and steel from Westphalia to Amsterdam, a distance of 147 miles, for 6s. 4d.; or to Antwerp, a distance of 173 miles, for 7s. 6d.

Competition Here Between Firm and Firm and in Germany Between Country and Country

It will be seen, therefore, that British iron and steel manufacturers labour under a considerable commercial disadvantage in respect of railway rates; and when we remember that that disadvantage is in respect of a business which is concerned with the constant hauling of huge masses of material, we understand that the United Kingdom is not realising all the advantages she ought to do in respect of the fact that Nature made her a small country with good ports, well suited to commerce.

Another important point is the question of commercial organisation. There is a greater co-operation between the various iron and steel units of Germany than there is in the United Kingdom. The German steel trade surveys the home and foreign markets as a whole, and organises an industrial plan of campaign. The German trade is better able to regulate and increase output than the British trade, the members of which do not sufficiently co-operate with one another.

With the world as a whole developing at an extraordinary rate, and exhibiting the insatiable appetite for iron and steel

which is shown so clearly in the tables on pages 1953 and 1954, there seems no good reason why British iron and steel masters should not entertain the ambition of enlarging their outputs and exports. The uses of iron are practically unlimited, and even in the old countries of the world there is still room for an enormously greater use of the most valuable of metals.

The Enormous Possibilities of Expansion Open to Iron and Steel Manufacturers

Moreover, if we consider what a small part of the world has as yet been developed to any great extent, we realise that there are no practical limits to the dimensions of the world's iron industry, short of those which are defined by the supplies of fuel and material. The call for railway iron and steel alone has increased and is increasing very rapidly; and the railways of the world will soon be calling for twenty million tons a year of rails, chairs, bolts, fish-plates, and sleepers. Moreover, the uses of iron in building are ever extending. The modern large building is a skeleton of iron or steel, encased in concrete, with a facing of masonry; and it may be observed that iron so built in is lost to the iron trade for a very long period--*i.e.*, that it does not become scrap-iron for a century or more. Rapid, then, as has been the world's iron and steel development since 1900, the next quarter of a century is like to see an unprecedented expansion of the trade. When, then, we remember our wonderful command of good ports and shipping, we can afford to entertain large and legitimate ambitions with regard to the development of the British iron and steel trade. We have about twenty first-class ports, as compared with only two possessed by Germany, and even the United States itself cannot compete with us in this respect. None of our iron centres is more than about seventy miles from a fine port, whereas the American ironworks are from 500 to 1000 miles from the sea. We ought, then, to be able to play a great part in the iron and steel developments of the near future.

The Necessity of Organisation to Make Use of Britain's Inherent Economic Advantages

There is every reason why we should set ourselves to organise power and transport facilities, and to make the best possible use of what are really great inherent economic advantages. In the very important table on page 1958 our considerable dependence on imported ore is clearly shown, and this table also helps us to realise how stationary British iron production has been for a considerable period. The number of furnaces does not show this; it has diminished, because the modern blast-furnace is of much greater capacity than that used in former years. When we turn to the ore used, and to the pig-iron produced, however, we see that in 1910 we consumed only about four million more tons of ore than in 1880. The variation in the price of iron is worth special attention. In the last few years iron and steel advanced to the high prices of forty years ago.

The question of iron-ore supplies is an all-important one for the iron manufacturer. We have good supplies of native ore, but much of it is poor in quality. Cleveland iron ore, for example, is exceedingly poor in metallic content, but there is plenty of it, and it is so close to coal and to a port that it can be used economically, whereas it would not be worth while to import it from Sweden or from Spain. The ore we import is usually of a higher metallic content than native ore.

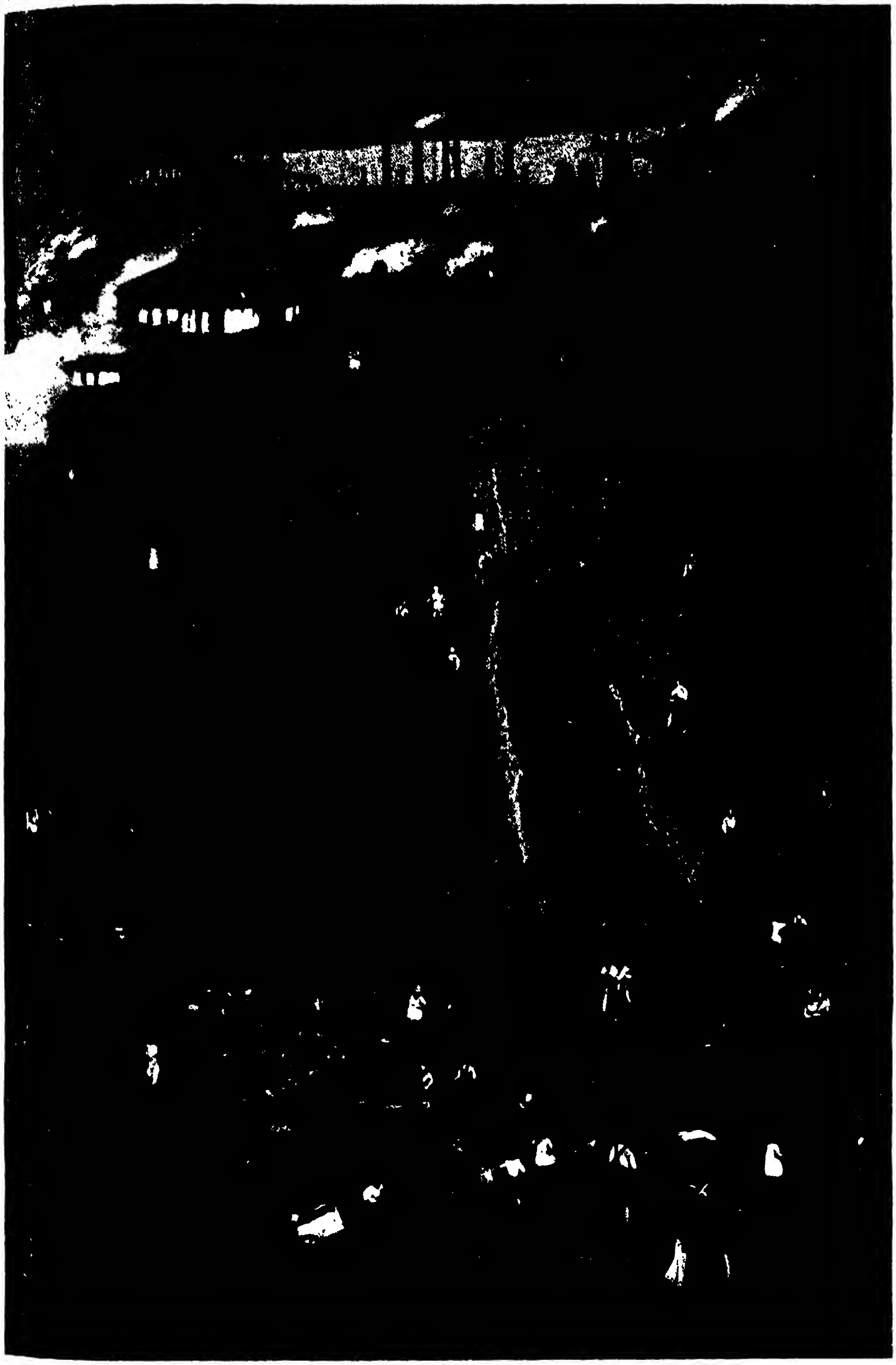
How Invention Has Made the Use of Impure Ores Possible and Remunerative

Iron ores vary greatly in character. Roughly, they may be divided into phosphoric and non-phosphoric, the former term being applied to those which contain more than a very small trace of phosphorus. It was not until the 'eighties that it was found possible to eliminate phosphorus from phosphoric ores, and so enable them to be brought into commercial use. It was in 1879 that Mr. Sidney G. Thomas read to the Iron and Steel Institute a paper describing what is now termed the "basic process" of steel-making, which not only utilises phosphoric ore, but gives a slag which is a most valuable manure.

Briefly, the process consists in lining the furnace hearth or Bessemer converter with material containing a good deal of limestone, which absorbs the phosphorus. Lime is also added during the steel-making, and this completes the absorption. This discovery has had a remarkable result upon the steel industry of the world. Nearly the whole of the gigantic German steel output is of basic steel. The British invention proved to be of far more importance to Germany than to England, because Germany has so much phosphoric ore. Thomas's discovery meant, in effect, giving value to hundreds of millions of tons of ore which before were useless.

It is not at all certain that the future will make our position with regard to iron ore worse than it is at present. It is true of the world as a whole that it is creaming

WHY IS THE USEFUL DEFILED BY THE UGLY?



THE HIDEOUS HOUSES OF THE PEOPLE WHO SMELT THE IRON WHICH RULES THE WORLD

THE PRODUCTION OF BRITISH PIG-IRON FOR TWENTY-FIVE YEARS.

Year	Furnaces in Blast	Pig-Iron Produced	Total Iron Ore Used	Imported Iron Ore Used	Coal Used	Average Price of Exported Pig-iron, f.o.b.
	Number	Tons	Tons	Tons	Tons	s. d.
1875	629	6,365,000	16,500,000	459,000	15,646,000	72 6
1880	567	7,749,000	21,087,000	2,633,000	16,983,000	63 10
1885	424	7,415,000	17 938,000	2,823,000	15,287,000	43 1
1890	414	7,904,000	19,214,000	4,472,000	16,168,000	60 11
1891	376	7,406,000	18,518,000	3,181,000	15,374,000	52 4
1892	302	6,709,000	16,344,000	3,780,000	13,860,000	51 1
1893	327	6,977,000	16,621,000	4,066,000	13,807,000	46 11
1894	325	7,427,000	17,804,000	4,414,000	14,885,000	46 0
1895	344	7,703,000	18,629,000	4,450,000	15,224,000	47 11
1896	373	8,660,000	21,204,000	5,438,000	17,114,000	47 10
1897	380	8,796,000	21,327,000	5,969,000	17,552,000	48 1
1898	358	8,610,000	20,958,000	5,468,000	17,196,000	52 6
1899	411	9,421,000	22,820,000	7,055,000	19,061,000	69 4
1900	403	8,959,000	22,101,000	6,298,000	18,742,000	84 0
1901	336	7,929 000	19,265,000	5,549,000	16,273,000	62 8
1902	348	8,679,000	20,928,000	6,440,000	17,649,000	64 9
1903	349	8,935,000	21,879,000	6,314 000	18,302,000	63 1
1904	327	8,694,000	21,146,000	6,101,000	17,535,000	58 5
1905	345	9,608,000	23,051,000	7,345,000	19,255,000	63 0
1906	368	10,183,000	24,670,000	7,823,000	20,863,000	69 11
1907	369	10,114,000	25,124,000	7,642,000	21,119,000	74 2
1908	322	9,057,000	22,735,000	6,057,000	18,742,000	63 5
1909	319	9,532,000	23,691,000	6,922,000	19,463,000	64 10
1910	336	10,012,000	24,864,000	7,630,000	20,485,000	68 4

the best of its iron ore *i e.*, of the ore richest in metallic content, and which can be most cheaply mined and smelted. The passing of twenty years; therefore, may equalise conditions with regard to ore, rather than increase our relative disadvantage. We have enormous quantities of second-best ironstone. Germany, as she increases her iron output, is compelled to import more and more of her raw material. Indeed, her imports of iron ore have increased about six times in the last ten years. These considerations encourage us in an optimistic outlook with regard to the British iron and steel industry as long as those who conduct it fit themselves to play their part in what must be an ever-increasing trade. The old monopoly of the industry has, of course, gone for ever, but it is quite possible to expand the present British output far beyond its present dimensions, and not only to maintain but to increase one of the leading branches of our vitally important oversea trade.

Nothing is more curious in the study of commerce than the widely differing customs which spring up in different trades. We have seen that in the leading vegetable fibre employed in textiles—viz., cotton—there is extensive gambling in " futures," and yet that in the chief animal fibre employed in the textile industry—viz., wool—gambling in " futures " is unknown. When we come to iron and steel, we again find a commercial method which lends itself to speculation which is often harmful to the real interests concerned.

Iron has its " warrant market," which had its origin in ironmasters raising money upon their unsold iron, and so creating paper " warrants " representing so much iron. A system of iron warrant stores came to be established under the control of independent parties, who issued certificates, or " warrants," which, representing iron in the store very much as a Bank of England note represents gold in the Bank, came to be a negotiable security. The establishment of such a system obviously leads to the possibility of unreal buying or selling, to take advantage either of an expected rise or an expected fall in price. There is an active market in iron warrants, as in readily negotiable stocks and shares, and the market remains at Glasgow, where the system of warrants originated. Curiously, however, there is no longer a market in Scottish iron warrants. The Scottish iron manufacturers found that the market was inimical to their business, and a few years ago they therefore discontinued sending their iron into the Glasgow store. Strange to relate, however, Cleveland iron warrants are dealt in on this Glasgow

iron market. It is very remarkable that stores of Cleveland iron at Middlesbrough should be coined into paper "warrants," and those warrants gambled in at Glasgow. The price of Cleveland iron is formed by the play of forces on the Glasgow market; and the manufacturer who sends his iron into the warrant stores on the Tees has to look to Glasgow to know what is the current price of his own production.

The Advantages and Disadvantages of the Paper Warrant System in Marketing Iron

Obviously, warrant stores may be a great convenience to a manufacturer, since they enable him to ease his finance at a time of poor demand and accumulating stocks, but it is very questionable whether the disadvantages of the system do not more than counterbalance the advantages. It is a system which has no enduring qualities; and the elimination of the Scottish warrants shows that manufacturers realise the folly of making real and legitimate trade the sport of unreal and illegitimate transactions. The iron market cannot be acquitted of having harassed the British iron trade severely on more than one occasion.

It has been said in defence of the warrant stores that such stocks have a tendency to steady prices, but examination of prices does not favour that conclusion. In 1888 and 1891, for example, when from 600,000 to 1,000,000 tons of iron were in stock in the Scottish warrant stores, prices were exceedingly variable; in 1889, with a warrant stock of a million tons, the price of iron varied between forty shillings and sixty-four shillings per ton. Such variations as these are symptoms of the imperfection of commercial dealings. They are a constant trouble to the manufacturer, whose thoughts have often to be more concerned with the commercial than with the industrial side of his work. Probably we shall not get rid of such untoward symptoms until there is a much wider co-operation throughout the world between the members of a trade, and the establishment of markets free from the bugbear of the speculative middleman.

The Movement to Form a World-wide Organisation of Industries Based on Iron

Undoubtedly the iron and steel world is full of projects for combination and co-operation, and every sign points to the world-wide organisation of the essential industries. In 1911, at Brussels, a conference of the world's ironmasters was held at the suggestion of Judge Gary, Chairman of the great United States Steel Corporation. Britain, Germany, France, Austria, America, Canada, and other countries were represented, and an International Iron and Steel Association was formed, charged with the general oversight of the world's iron production, with a view to the co-operation of the producers concerned in matters of output, markets, prices, etc. That is a very remarkable stage in commercial development, and it undoubtedly points along the road to world peace and world co-operation.

Such an organisation has, of course, possibilities both for evil and for good, but undoubtedly in the long run the good will outweigh and supplant the evil. It is surely far better for the iron producers of the world to be working co-operatively than to be cutting each other's throats, and illegitimately dumping material upon each other, not for the purpose of legitimate export, but in order to hamper and harass a rival and to create difficulties for capital and labour alike. Nothing could be better for the progress of the iron and steel industry as a whole than that the entire world of iron should be surveyed scientifically by the world's iron-captains acting co-operatively.

The Need for the Conservation of the World's Iron Stores Against Days of Iron Famine

Proper survision of the world's iron resources is a great and growing need. Again reminding ourselves of the acceleration of the use of iron shown in the table on page 1953, we see that without conservation the passage of a few decades may bring us, if not to an iron famine, at least to greatly appreciated iron prices, which would sadly hamper all the work which depends on iron. The grey metal is so indispensable to man that dear iron would be nothing short of a calamity for the world. If, therefore, by world-wide co-operation ironmasters could gain freedom from commercial strife, and have more time and brain to devote to technical work and industrial organisation, all users of iron would have reason to be thankful.

Science will doubtless do much for us in the future by enabling us to make economic use of the lowest grades of ores, which are now neglected because of the impossibility of putting them to commercial use in competition with richer material. It is the duty of commerce, however, to co-operate with science in iron conservation, and to help to place at the disposal of mankind an assured supply of a metal the use of which has wrought such far-reaching changes.

THE FARMS THAT FEED THE HOMELAND

DESCENDANTS OF ENGLISH YEOMEN SOWING WHEAT IN AUSTRALIA

SHIPPING WHEAT AT MELBOURNE FOR THE MARKETS OF ENGLAND

The picture on page 1964 is reproduced by courtesy of Miss E. M. Leonard

THE LAND AND THE PEOPLE

How the Anglo-Celtic Race Ploughed its Way over New Continents with Unprecedented Speed

BALANCE OF AGRICULTURE AND INDUSTRY

Thus far in our study of the evolution of society we have kept to the general course of development of the entire human race. This, we hope, has served to bring out clearly the fundamental events in human society that link the lowest races with the highest, and form the foundations on which all advances have been made. "We must remember the past, and look to the future," was a favourite saying of one of the greatest of modern men of science, Louis Pasteur. Yet we often reach a point at which some of the forces acting from the past are so complicated with a web of forces of recent creation that it is difficult to discern how much of the old is still effective in the new conditions.

In these circumstances it seems best to attempt first to disentangle and measure, as well as we can, the new forces of the present age. Presuming that we remember sufficient of the past to avoid mistaking ancient and elementary facts of human nature for wonderful novelties of a bad or good sort, we may be able to estimate what real advances in civilisation have been accomplished, and in what direction the most progressive races are moving.

For instance, we have already seen that civilisation is primarily based on agriculture and stock-breeding. Abundant and regular food supplies are the basis on which all the new machinery of human life has been constructed. Obvious as this fact is, we are often in danger of forgetting it in studying some of the leading societies of the present day. The people of Great Britain especially seem to be strangely divorced from their fruitful soil. The majority of them live wholly in the present, and regard their purely industrial and commercial activities as a natural, healthy, and permanent form of national life. They watch with pleasure the progress over the whole civilised world of the industrial revolution engineered by their race; and they sometimes fancy that what Great Britain is, all the other highly advanced countries will become. They do not understand the extraordinary conditions under which they live.

On the other hand, there is a school of writers among us who regard the industrial revolution and all its results as a tremendous disaster, which is bringing about the complete ruin of the race. In their view, we are selling the vigour of body, which we should hand down to our offspring, for the poisonous pleasures of life in our great manufacturing cities. We are capitalising the vital resources of the race and spending them wastefully and foolishly, and calling the crime "progress." This way of looking at the industrial civilisation on which most of us pride ourselves seems, at first glance, to be as true as it is unpopular. Oliver Goldsmith put it into verse in 1770, just when the industrial revolution was beginning:

Ill fares the land, to hastening ills a prey,
Where wealth accumulates, and men decay:
Princes and lords may flourish, or may fade;
A breath can make them, as a breath has made;
But a bold peasantry, their country's pride,
When once destroyed, can never be supplied.
A time there was, ere England's griefs began,
When every rood of ground maintained its man;
For him light labour spread her wholesome store,
Just gave what life required, but gave no more;
His best companions, innocence and health;
And his best riches, ignorance of wealth.

To bring this prophecy home to every member of our huge urban population, it is only necessary to omit the references to the flourishing and fading of princes and lords, and substitute for it some remark about the rising or falling of the general standard of comfort. A numerous and healthy peasantry, owning the soil they

till, and feeding themselves and the nation, and sending a constant stream of new blood into the cities, is of more permanent value to the race than all that we have done by steam-driven machinery and other means of cheap production. Such, we take it, is the extreme view obtaining in a certain school of writers throughout the civilised world. Reduced to practice, this view often leads to fierce and continual conflicts between the agricultural and industrial interests in a state. The urban population has to be compelled to pay dearly for its food in certain civilised countries so that the farming classes may keep the land in profitable cultivation.

In Europe this problem of the balance between the agricultural and industrial activities of a people is often complicated by the existence of a powerful governing class of landowners. The large landowners of Germany, for example, are fighting for their own hand against the wealthy manufacturers of the cities, who, they fear, will despoil them of their political and social power. Yet if the great landowners are removed, the fundamental antagonism between agriculture and modern industry seems still to endure. At the present time it is most clearly seen in China, a vast, overcrowded, and self-contained community, in which the struggle for life has gone on with an intensity terrible to think of. For hundreds of years China has possessed an enormous and intelligent population, with an uncommon skill in various kinds of craftsmanship. Yet she has not become an industrial empire, in spite of her vast coal mines and other mineral resources. For it was impossible to divert the energies of a large part of the people from the cultivation of the soil. It would have meant famine. Japan, at the beginning of her recent industrial expansion, was faced with the same difficulty, though in a less acute form. She solved it, as is well known, by taking Korea as her granary.


ROBERT BAKEWELL

Perhaps modern China will at last be able to become largely an industrial nation by selling her minerals and manufactures for vast foreign food supplies. In this case, the artisan and urban classes of all the white races will have occasion to see that agriculture is the solid and original basis of civilisation. The agricultural states, in the fierce competition for their produce, will be in far the best position. It is not at all unlikely that the industrial movement will have spent much of its force in the next hundred years. It will be checked and limited by the rising cost of bread and meat; and when the ordinary farm-hand is able to earn as good wages as the ordinary miner, the balance between agriculture and industry will be restored. Very few nations will then be able to afford the extremely questionable luxury of engaging almost entirely in industrial pursuits.

Here the case of our own country appears to the alarmists to be of general importance. For it is in Great Britain that the effects of the industrial revolution are most evident. We were the first country that changed the entire constitution of its national life in order to develop its manufactures. And on us, it is contended, there have fallen the disasters in store for all other nations who follow our example. At present we are attempting to get the people back to the land by various Acts of Parliament for the extension of small-holdings, but none of these measures is quite successful. Yet the sudden collapse of the industrial and commercial greatness of Athens is a warning of the inherent weakness of a community which can procure its food only while its command of the sea lasts.

Having thus presented the views of the writers of the extreme agricultural school, who see nothing but disaster in the development of our industries at the expense of our home food supplies, we shall attempt to examine in an equally impartial manner the other side of the case. In the first place, the present state of British agriculture is not unparalleled in our history. Three times in the last three hundred years or so has a vast multitude of the sons of our soil been swept from the land. We have had more revolutions in agriculture than any other nation; and, in the writer's opinion, it has yet to be proved that our people generally

have not managed in the end to benefit by changes that at first seemed disasters. There was a time when, as old Camden said, the English sheep became the most ravenous and terrible of beasts. It ate up farms, it laid waste villages, it destroyed towns. About three-quarters of a million of men, in a country whose population did not exceed five millions, were driven off the land by the mischievous sheep. England was full of starving beggars; and Shakespeare, who saw them and pitied them, describes how they were whipped from "tything to tything, and stock'd, punish'd, and imprisoned." The explanation was that, at the end of the feudal era, a merchant class arose who looked at the land solely with an eye to profit, and saw that sheep-farming was more profitable than subsistence farming.

The new commercial aristocracy converted their estates into parks or sheep-walks, where only a shepherd found employment. The commons were enclosed by force, or by connivance with the principal commoners. Small tenants were evicted from their holdings; farm servants were dismissed, the cottages of labourers were pulled down, and the wastes, on which they used freely to pasture their pigs and poultry, were thrown into sheep-farms. Rents rose exorbitantly, and by 1595 the wages of farm-hands fell to less than half of what they had been. It took a man forty-eight days to earn the food that he used to win in twenty.

There were numerous agrarian insurrections, and several Acts of Parliament were passed in a vain attempt to promote agriculture. The English sheep of the sixteenth century was as destructive an animal as deer now are in the Scottish Highlands. What the deer-forest has done, and is doing, for the small crofter, the English sheep-run did for the peasant farmer. The misery of the labourers was enormous; and with the aim of getting some of them back on the land, Queen Elizabeth made a law that no cottage should be built for a farm-hand without four acres of land being given to him for his use. This had a good effect when grain became so scarce that there was a general movement to revert to tillage. And it is estimated that in the days of Cromwell there were 180,000 farmers tilling their own land out of a population of five and a half millions.

England soon became the granary of Europe. Yet the men who had been driven off the land never came back. The abundance of cheap labour started the factory system in the sixteenth century, and led, in other ways, to a purely capitalist organisation of various industries. The result was that in the eighteenth century the population doubled, while the number of cultivators decreased, not only relatively but actually. The country ceased in 1770 to export corn, and the price of meat and bread began to rise just as the industrial revolution was beginning. This led to the second great crisis in English agriculture. It was absolutely necessary either for the food resources of the people to be largely increased, or for the industrial development of the nation to be brought to a standstill, as had happened in China.


THE SECOND VISCOUNT TOWNSHEND

The situation was saved by two English inventions in the science of farming, which are of quite as much importance to the world as were the inventions of the spinning-jenny and the steam engine. In the old system of tillage, one third of all the tilled land of England was utterly useless. It had to lie fallow for a year to prevent the soil from being exhausted. Village communities divided their arable land into three large fields. On one field nothing was grown, and the other two fields were divided into strips, and apportioned among the commoners according to the extent of their holdings. It was a primitive and wasteful arrangement. No green crops were sown for the cattle, and the beasts grew so thin and starved in winter that, where it was possible, they were slaughtered in autumn and salted down as winter meat to save the cost of feeding them.

Such was the system of tillage and stock-

breeding which was destroyed by two men, of one of whom a French writer has said: "Bakewell was a man of genius, who did as much for the prosperity of his country as his contemporaries, Arkwright and Watt." On the one hand, Townshend and his successors introduced a new method of cultivating the land which increased in a marvellous manner the fertility of the soil. On the other hand, Bakewell so improved sheep and cattle that he transformed entirely the art of stock-breeding, and provided beef and mutton for a million persons, out of flocks and herds on which, at an earlier date, thousands would have starved. Had it not been for these two men and their disciples there would have been no great industrial revolution. It would have been impossible to feed the enormous multitudes that were entering the mills, factories, and workshops of Great Britain. The half-empty countryside, with a third of its arable lands lying fallow, and its sheep and cattle with no flesh on their bones, would not have provided bread and meat for the overgrown artisan classes.

Moreover, the marvellous growth of the Anglo-Celtic race over-seas would not have taken place; and the population of other countries that have followed Britain in building up great industries would have been checked. Thus we see that the English revolution in agriculture was a necessary preliminary to that industrial revolution on which modern civilisation is founde In both cases the Anglo-Celtic race forge and perfected the instruments of advanc and profited greatly by its inventions. Th possession of new means of obtaining larg food supplies enabled the various colonisin branches of the race to expand in numbe and power and wealth at an incomparabl speed. Sometimes in the lifetime of th first emigrant, a small settlement grew into a nation, and began to take part i feeding the people of the motherland.

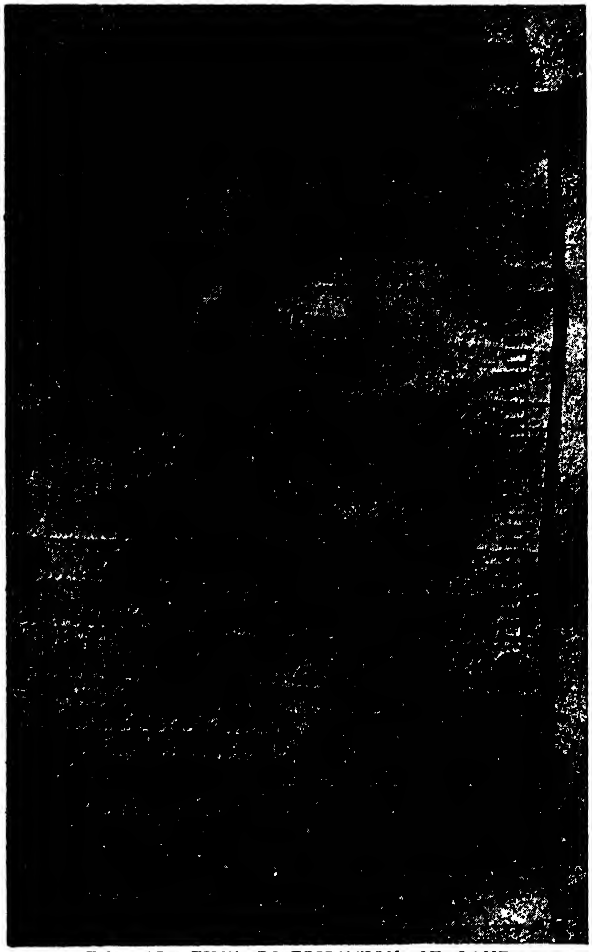
Marvellous as is the speed with which th Anglo-Celtic race has ploughed its wa over a considerable portion of three con tinents, yet the motherland has paid a heavy price for the two inventions i agriculture and stock-breeding that mad this expansion possible. In the system o tillage developed by Townshend none o the land was allowed to lie fallow. It wa divided into four fields, in which roots an grasses for cattle and sheep were alternatel grown with cereals. By this rotation o crops the land that used to lie empty wa enriched with nitrogen. Moreover, th manure that had been allowed to remain o the rough waste lands, where the cattl grazed, was more profitably employed in in creasing the fertility of the cultivated soil

Unfortunately, this scientific system o tillage could not be adopted by villag communities. Each man had only scattere strips of ground in the unenclosed commo

A COMMON FIELD IN THE NINETEENTH CENTURY, SHOWING DIVISION BY BALKS

fields. It was not unusual for a cultivator to hold his arable land in thirty or more separate pieces; and it was useless for him to attempt to improve his scattered allotment, as the land was redistributed every year, and the third part of it thrown out of cultivation. It was also impossible for the small common field farmer to improve the breed of his sheep and cattle, for the new pedigree stock commanded prices far beyond his means. Thus, the profit of the new inventions fell to wealthy owners of large estates who were able to make costly experiments in tillage, and pay as much as a thousand guineas for a new bull or ram.

Yet the population of the country was increasing, and land was going up in price, and it was necessary to grow more wheat and breed more and better sheep and cattle. So the Government intervened with a system for enclosing the common fields. When a parish was enclosed, its open fields and meadow and waste land were redistributed among the common owners. They were given an enclosed holding equivalent to their scattered holdings in the open fields and to their rights of meadow and waste. In each case the tenure was unaltered. Leaseholders obtained a new leasehold, copyholders a new copyhold, and freeholders a new freehold. The difference was that the holdings were enclosed and self-contained farms, instead of scattered and changing allotments in the open and common fields all similarly farmed.



THE OLD-TIME DISTRIBUTION OF LAND

This plan of an open field at Dean Manor, Oxfordshire, forming part of the estates of Oriel College, Oxford, shows how the land was divided in strips among its various owners, in order that one man should not have all the best land.

Nowadays we are so accustomed to the sight of the land of the country being divided into self-contained farms, which are further divided by hedges into small fields, that most of us have no conception of what England was like a hundred and fifty years ago. It was a land of open fields, split up into allotments that changed hands every year; and the cultivated soil was poor in quality, limited in quantity, and surrounded by vast tracts of heather and gorse. On the wild stretches of the waste, however, many cottagers and small farmers managed to keep a cow, a few pigs, a flock of geese, and a number of fowls. This class was sorely hit by the enclosures. The large farmers did well; for the new methods in agriculture enabled them to make their enclosed farms two or three times as profitable as their scattered holdings had been; but the few acres that a small-holder obtained did not compensate him for his lost grazing rights.

The result of the enclosures, therefore, was to make the land more fertile, so that it provided bread and meat for the growing industrial population. But the small-holders were ruined and flung into the factory towns. Discoveries in the arts of tillage were continually made, with the result that crops increased in size, while the number of farm-hands diminished. It was found that large farms were most profitable; and under the large farm system England became the most fertile land in the world after Belgium with her small farm system.

At the present time half the enclosed soil in England and Wales is owned by about 2250 proprietors. Of about half a million cultivating holders, only about 60,000 own the land they work. In the ordinary way, the English manor, with its village community, should have developed into a system of small-holdings, by means of which a considerable portion of the population would still be attached to the soil. That is what has occurred in various parts of Europe. But this development was prevented in our country by the fact that the three-field method of working the land was suddenly overturned by the agricultural inventions of the eighteenth century.

The Effects upon the British Race of the Agricultural Inventions of the 18th Century

In its relation to the land, the British race is both enjoying and suffering from the results of a spirited, inventive, and adventurous policy in the arts of tillage and stock-breeding. It has flung itself on America and Canada, New Zealand, Australia, and South Africa, and it has also obtained a large control over the wheatlands and cattle-farms of the Argentine. Neither military power nor money power alone could have produced so vast and rapid an expansion of a small island people. Behind it were Bakewell's invention in stock-breeding and Townshend's roots and clover. These inventions ruined the small British cultivators, and led to the system of large farming, which has further been promoted by the application of steam and petrol machinery to tillage.

Yet, though the motherland is like a woman exhausted by bearing and suckling a swarm of young giants, the general strength of the Anglo-Celtic race is tremendous.

The Fertilisation of the whole Earth by the Scattered Skill of the British Race

We must not compare the 180,000 yeoman farmers in a population of five and a half millions in the Cromwellian age with the exceedingly scanty proportion of their descendants now in England. We must take the larger and the truer view of one the most extraordinary events in history. The descendants of the ancient yeomen are scattered about the wheatlands, cattle-farms, and sheep-runs of Northern and Southern America and Australasia. They mingle with the Boers of South Africa, and the Spaniards of the Argentine. They are now helping to develop Rhodesia and Saskatchewan, and they will soon be found in Uganda, as well as in the tea plantations of Ceylon and Assam, where they have beaten the Chinese in skill and knowledge. Lately they built up rubber plantations in the tropical wastes of Malaysia; and they are now planning to cover the Niger country with cotton-fields. When cane sugar does not pay in the West Indies, they become banana-growers, and introduce a new, cheap, and popular food to the hungry people of the motherland.

It is these far-scattered sons of our ancient soil that have brought about the third revolution in British agriculture, and made even large farming an unprofitable enterprise in the home country. So now the great estates of Britain are being broken up, and £2,500,000 worth of land has come into the market in the last two years. Here is a chance for the small-holder with a little capital to come into his own again, but we doubt if he will take the chance. So long as our Colonial farmers can grow more crops and raise more sheep and cattle than they need for their own consumption, they will continue to keep British agriculture in a state of depression.

Why at Present the Manhood of Great Britain Will Not Go Back to the Land

There are two ways in which they do this. First of all, they empty the motherland of many of its best and most enterprising farmers, by offering to them advantages superior to those that can be obtained at home. And secondly, as they possess vast tracts of virgin soil which they cultivate with the latest machinery, or convert at little expense into magnificent pasture lands, they are able to sell their produce at prices with which few British cultivators can compete. Besides, in many cases they possess a less variable climate than ours, so that the returns for their labour are generally more regular than the returns the British farmer gets on an equal amount of capital and work. In fine, their advantages are overwhelming.

One of the grand results of a century of industrialism has been to raise the general standard of comfort so high that the life of an agricultural labourer at 17s. 6d. a week has little attraction either for the labourer or anybody else. Nobody wants to go back to the land, and nobody means to—at least, not in Britain under present conditions. Undoubtedly there are many men who like a country life and would rather work under the open sky than in the shelter of a factory or office. But these men and women are not going back to our land. They are leaving it, and settling in multitudes in our prosperous agricultural colonies.

It is extremely doubtful if the motherland of the now widespread Anglo-Celtic race will ever again be in a position to maintain its industrial supremacy while drawing all the bread and meat it needs from its own soil. In all probability, Canada and the Argentine and Australasia and South Africa will follow the same course of development as the United States, and absorb at last their magnificent food supplies in building up huge industrial populations of their own. The United Kingdom will then be compelled, by the very high cost of living, to establish again the natural balance between its industrial energies and its agricultural activities. This will happen, we expect, in less than a hundred years. Perhaps our country will then become less wealthy, less powerful, and less densely populated, though its inhabitants may be on the whole happier and more healthy.

On the other hand, new inventions, new devices, and fresh sources of power may enable our little island kingdom not only to feed itself from its own soil, but to direct an immense army of machines that will maintain a greater number of industries than those now based on its coalfields. After all, the race that engineered both the industrial revolution and the agricultural revolution is still one of the most spirited, inventive, and adventurous of peoples. It is still enjoying the cheap food and the cheap manufactures that it bought by an effort of mind; and there is no reason to suppose that, when it finds another effort of mind is necessary, it will not be equal to the occasion. We have never been a frugal, saving, cautious people like many of the Continental nations. Again and again we have got into terrible difficulties through extravagance and carelessness. But these very difficulties have called out and brought into full play the genius of our best minds.

THE RICEFIELDS ON WHICH CHINA EXPENDS HER ENERGIES TO FEED HERSELF

At the present time, the attraction of our cities and the attraction of our Colonies prevent us from adopting the system of small-holdings which, as Continental examples seem to show, is the only solution of the problem of maintaining a balance between industry and agriculture. The life of the small-holder is too severely laborious to appeal to a race that owns several continents of fertile soil and temperate climate. So, in spite of the breaking up of our large estates, we shall probably let pass the opportunity for re-establishing the army of State tenant-farmers contemplated by our recent Small Holdings Acts.

But then we have a genius for turning lost opportunities into a stimulus to larger progress. Nothing in the history of the great farming races of the past can apply to the present anomalous position of the people of Great Britain. The degenerate mob of Rome, for instance, did not more than make up by its industrial skill for its neglect of the arts of agriculture. The motherland of the Anglo-Celtic race has been no parasite on its Colonies and its tropical dominions. It has, indeed, given to the whole world, in ideas and machines, in money and minerals and manufactures, more than it has yet received. The only danger in the present want of balance between its agriculture and its industries is the danger of its food supplies being cut off by war. This could be obviated by establishing national storehouses—a scheme that would at once cheapen meat, by destroying the monopoly of the Chicago ring that now has a large control over the British market. Except for this danger of war, there is nothing to be done but to leave to the general genius of the British people the task of looking after its future food supplies. The statesman must once more wait for the inventor.

THE HEIR TO ALL THE AGES

BY T. C. GOTCH

THE DOCTOR OF THE RACE

The Science that Finally Applies all Other Sciences for the Upbuilding of Mankind in Health and Happiness

THE FOUNDATIONS OF EUGENICS

WE have seen what the Eugenist demands, why his ideas and ideals are entitled to a new word for their expression. If we continue to think and to study we find that the new word may be used in two ways, which are distinct, and must be distinguished. When we speak of Eugenics we may think of it as a science, or we may think of it as a practice. We may make calculations or experiments on heredity in a laboratory, or we may study and compare marriage customs in various communities, and may call such work eugenics. Or we may frame and enact legislation, based upon our researches, or methods of education of the young, in accordance with what science teaches us, and we may call this kind of work eugenics. The one aspect of eugenics shows it to be a science, and the other shows it to be a practice. We must distinguish between these two, and make up our minds, when we speak and think of eugenics, whether we mean a science, amassing knowledge quite apart from any use and purpose, or whether we mean a practice, which applies knowledge for certain ends.

Sir Francis Galton used his own word in both senses, inclining more and more towards the conception of eugenics not as a science, like astronomy, but as a practice, like medicine. This is the exact parallel, as we shall see at once. There is such a thing as scientific medicine, but every doctor knows that there is no science of medicine. Medicine is a practice, as the phrase " medical practice " implies. It is a scientific practice, or should be, because it is based upon certain sciences. The medical student studies preliminary sciences, like physics and chemistry and botany and zoology; then he studies what are sometimes called the " medical sciences," though they do not need or imply the treatment of anybody—such sciences being anatomy, physiology, pharmacology, which is the special study of the action of drugs, bacteriology, pathology, which is the science of disease and disease-processes. Lastly, the student takes up the practice of his science, and that practice is what we mean by medicine in the proper sense of the word.

It is not a science, but a scientific practice, based upon a number of sciences, developing and altering as they develop and alter. The anatomist is simply an anatomist: his study may equally serve the purpose of the surgeon or the executioner. The pharmacologist studies drugs: his science may equally serve the doctor who gives some rare poison to soothe convulsions, or the murderer who hopes, by the application of this rare knowledge, to escape the gallows. The bacteriologist studies microbes: the consequent practice may be that of the doctor who controls a cholera epidemic by knowing how best the microbes may be killed, or that of the blackguard who injects cholera microbes with murderous intent. These illustrations are drawn from actual recent events, and will clearly show the distinction between " the science and the practice of medicine."

Now, eugenics is racial medicine—though it is also more—which endeavours to cure and prevent the diseases of the race, bodily and mental, as ordinary medicine seeks to cure and prevent the diseases of the individual. It is, above all, a practice. When the writer divided Natural Eugenics into its three departments, he did not call positive eugenics the study of worthy parenthood, but " the encouragement of worthy parenthood." The study must come first, but it is the consequent action that is the eugenics; just as the doctor's diagnosis must come first, though it is his treatment that is the doctoring, and furnishes his title to our esteem. The Eugenist is the race-doctor,

trying to cure and prevent disease of the race, and to maintain, and amplify, and exalt its powers of body, mind, and soul.

Like every other practitioner, the Eugenist stands upon scientific foundations, and is at their mercy. He has a theory and an experience, and he calls upon whatever science will serve him for his end, exactly as the musician or the architect does. But eugenics is a new practice in our day, and there are no schools for eugenics. Yet, as there are schools for medicine or music, which can show us the names and order and relation of the sciences upon which the practice of the future doctor or composer or singer will be based, our business in the present chapter is to state, so far as we can in these early days, the scientific foundations of the new practice called Primary Eugenics.

If the superstructure is to be strong and tall and fine, and to serve the purposes of those who use it, the foundations must be wide and firm and deep. We have only to consider the appalling, loathsome, often indescribable history of medicine and surgery before the foundations of such things were so much as asked for, in order to realise how absolutely and wholly, at every point and in every detail, our practice of eugenics, like any other practice, must depend upon knowledge, and ever more and more knowledge.

How Science Has Profited by Investigations That Were Laughed At

Eugenics has the creed, the religious temper and ideals, which will use that knowledge for the making of wisdom—all the knowledge we have and all that we shall ever have. Nothing useful to our purpose is to be ignored, forgotten, rejected. There is every reason to believe that already the stone which some of the builders rejected will become the head of the corner. We must learn from other cases. Medical practice requires everything to build on—not merely physiology, but physics; not merely the analysis of the blood, but the analysis of the atmosphere. The great modern advance of medicine is due to its foundation upon sciences which no one supposed to have anything to do with it. A young French chemist distressed his teachers by wasting his time over minute living curiosities which could only be seen by the microscope; and he became the Pasteur who created modern medicine and surgery and stereo-chemistry. Later, in Pasteur's city, other chemists unearthed a new element called radium; and now the Radium Institute in London is curing certain diseases as they were never cured before. Similarly we might notice how modern metallurgy has given musicians pianos and brass instruments which enable music to do new things, though foolish musicians would laugh at metallurgy, as foolish doctors laughed at Pasteur.

If, now, we consider what eugenics demands, how it aims at making men like Pasteur and Curie and Wagner, and at making people who can appreciate them; and how it aims, with nearer prospect of success, at eradicating disease, and making its cure therefore superfluous, it will be clear that the scientific foundations of eugenics must be *as wide as science itself.*

The Study of Man in Social Union the Sum of All the Sciences

Forty years ago, Herbert Spencer showed how sociology, the science of society, was based upon and required preliminary study in all the lower sciences—lower in the sense of being more fundamental and elementary, such as physics and biology and psychology. Everyone now begins to recognise the truth of the assertion that the study of man in social union is the sum and summary and synthesis of all the sciences which study individual man, and life, and earth, and the laws of the Universe. The entire plan of this present work is clearly based upon this radical conception of the classification and correlation and order of the sciences, at which the greatest minds of the nineteenth century, like Comte and Mill and Spencer, worked so hard and well. Many people argue that there is no science of society, and they are *almost* right, for they mean that sociology builds upon the simpler sciences; and similarly many people argue that there is no science of the living being, because it is really none other than an extension of the sciences of physics and chemistry.

Eugenics Based Upon All the Work of the Older Sciences

Nevertheless, the student of life knows that, though he builds upon the same foundations, he does build; the student of society knows that though he builds upon the same foundations, plus the work of the biologist, he also builds; and the Eugenist knows that he builds and stands and aspires upon all the work of the older sciences. Sociology is the sum and summary and crown of the other sciences. Eugenics is the ultimate purpose for which and to which the whole structure of science must now be dedicated. Hence its final place in the present work—the plan of which indeed indicates the foundations of race-culture.

Further and more detailed guidance is

furnished by the fact that the race is composed of individuals, and that only through and by individuals will the Eugenist achieve his end. Therefore, all the sciences upon which practical medicine and hygiene repose are part of the foundations of eugenics, and must be studied by the Eugenist who would avoid disastrously erroneous conclusions. But, just as biology is more than physics and chemistry, and sociology more than its predecessors, so eugenics is more than medicine, and requires to recognise more sciences, wider and also deeper than any other practice in the world.

Eugenics Gives the First Place to the Science of Heredity

We are trying here to state the chief foundations of eugenics, but omissions are certain, just as omissions would have been certain in a statement of the foundations of medicine made a century ago. This is no more than a first statement ; time and the growth of knowledge, and the exigencies of practice, will improve and amplify it.

The science of heredity, or *genetics*, must take the first place. The science of breeding underlies the practice of good breeding, or eugenics. Nothing could be clearer, and the Greek terms exactly fit the case. The study of heredity is, of course, part of the study of life, and is sufficient unto itself, apart from any application of it, just as anatomy is sufficient unto itself, and needs no warrant in surgery. But the surgeon builds upon anatomy ; and the Eugenist builds upon genetics. This is not the place to discuss the methods and results of genetics, which is an essential part of the science of life, but it is the place in which to state clearly what genetics is, and to insist that the Eugenist requires the sanction and guidance of genetics, and must therefore study and obey it by every means in his power.

Methods of Studying Heredity. Mass-Statistics *versus* Individual Observation

The curious and remarkable circumstance is that genetics is a much younger term than eugenics itself, and the recognition of the real place of genetics is so new that no writer on eugenics has yet acknowledged it fully. Sir Francis Galton studied the processes of heredity by a special method, upon the results of which he proposed to set up the practice of eugenics. The essence of that method was that it did not analyse individual cases, but massed them together, and studied the results in the form of mass-statistics. The method has been used, of course, in other directions for many decades, but Galton applied it to the study of the living world. Neither he nor his cousin Darwin, nor anyone else in the scientific world, knew that heredity had already begun to be studied, in a monastery garden in Silesia, by another method, which is indeed the only method of all natural science, the experimental study and observation and analysis of individual cases. The value of this method, practised by the monk Mendel in the late 'fifties and early 'sixties of the nineteenth century, was not realised until the final year of that century ; and all subsequent progress in the study of heredity, which has already added more to our knowledge of the subject than all preceding time, has depended upon the employment of the experimental or scientific method. The present leader of these studies is Dr. William Bateson, until recently Darwin Professor of Biology at Cambridge, and to him we owe the name " genetics," by which the study of heredity is now known.

How England Lags Behind Through the Influence of Galton

Most of us have heard how Bateson's notable follower, Professor Biffen, has created valuable new types of wheat by experimental breeding on the principles of genetics, as first laid down by Mendel. That is the parallel to the ambition of eugenics, however remote may be its realisation. But evidently it is possible to breed wheat and sweet-peas and mice and fowls and observe the results, whereas eugenics deals with man, who cannot be experimented upon. This argument is constantly urged, first, by those who do not realise the unity of all life, and the possibility of arguing from one species to another ; and second, by those who still maintain that the laws of Mendelism do not apply to mankind, and that only the statistical methods first applied to these problems by the founder of eugenics are applicable to man.

Unfortunately, we are, in this country, a very long way behind. So far as general genetics is concerned, our workers, such as Bateson, Punnett, and Biffen, are in the very van. But so far as human genetics is concerned, the case is only too different. The immense influence of the great beginner persists ; and though the "genetists" or " geneticians "—they have not quite made made up their minds which to call themselves —are very rapidly and successfully invading the human sphere, the real place of genetics at the foundation of eugenics has still to be proclaimed in Great Britain, as the present writer has contended for several years.

It is part of the tragedy of science that many interests are so often against it. The commercial forces which spread broadcast all manner of other things, have not hitherto served scientific knowledge. Mendel's papers, which mark an epoch in knowledge, were unknown for thirty-five years, for it would have paid no one to reprint and publish them to the world at large. In somewhat similar fashion, the pioneer work of Mendel's followers in the United States of America upon man, work which has already entirely superseded anything that has been done in this country—with a few scattered and scarcely known exceptions—is yet without recognition here, while great opportunities and resources are being spent upon methods of research which have repeatedly betrayed their prosecutors, and the results of which have already been disproved by the exact method of individual and critical analysis.

The American Breeders' Association have formed a special department to deal with the problems of breeding as they are met in man, and to this they have given the name of Eugenics Record Office, coined and used by Galton in his first public steps in London. The Galtonian term, the Galtonian spirit and aim, are maintained, but the Galtonian or statistical method—to which Professor Karl Pearson, Galton's most distinguished follower, has given the name of biometry, or life-measuring—is no longer employed.

The American Desertion of the Methods of Galton for Those of Mendel

The workers in the American school of human genetics employ the method of first-hand individual observation, which was employed by Mendel, and which alone has ever yet afforded the discovery of truth in the natural sciences. Already most notable results have been obtained; and perhaps no better result can be desired to flow from the present exposition of eugenics than the application of these results in the legislation for the feeble-minded, which cannot much longer be denied admission to our statute-book. These results will, of course, be dealt with and recognised in subsequent chapters, as we consider the various eugenic issues upon which they bear.

Here the critical reader will interpose, asking whether the American students are experimenting with man, and, if not, how their work can be called genetic, and rated so highly. The simple answer, which will ere long need no repetition, even in this country, is that man experiments upon himself daily. Mendel mated peas, and man mates himself; the results may be observed in both cases. Only the observation must be critical and individual. The argument of the biometricians, that their method is independent of the quality of the material upon which it is brought to bear, is logically untenable, and has repeatedly led them to conclusions which further study, of a critical kind, has discredited. If the study of human breeding is to be worthy of the name of science, and of its descent from Mendel, there must be the same exact, detailed, scrupulous, first-hand study of every case as Mendel bestowed upon his peas.

The Comparative Uselessness of Observation on Only Two Generations

Now, that is exactly what the Americans are now doing, that is why their results transcend anything before them, and that is why those who have taken the necessary pains to acquaint themselves with this work are bound to protest that only by this method can we, in this country or in any other, prosecute those special studies upon which eugenics primarily depends.

Our work, hitherto, has almost exclusively dealt with two generations—parents and offspring. Great quantities of work, with most startling conclusions, are produced, dealing with the inheritance of alcoholism and tuberculosis, and with the influence of evil conditions upon childhood, and so forth, which are entirely based upon the study of two generations. Every student of genetics knows that until you have bred from the second generation, and found what the third consists of, your task is neither done nor really begun. Thus none of the work which deals with only two generations can any longer be accepted; unless the third generation can be traced and recorded, the figures and records are useless.

Precise Details of Heredity Needed to the Third and Fourth Generations

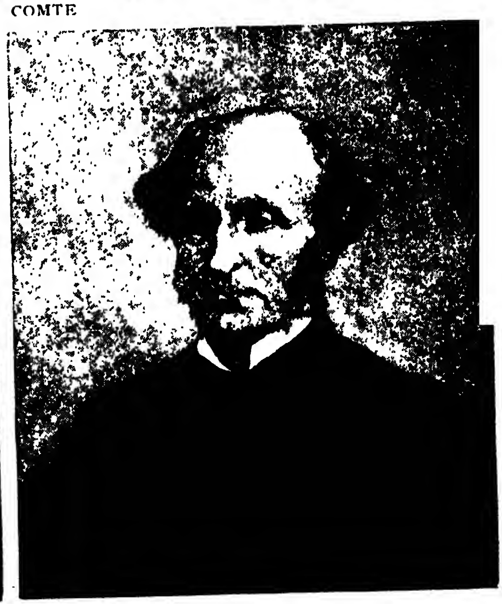
As Mendel proved, we must trace, to the third and fourth generation and further, the consequences of mating individuals of known ancestry. If the ancestry be not known, the experiment will be only half an experiment, and the result only a half-truth, more misleading than an entire error. The student of human heredity must therefore deal with individuals of known ancestry—which means that he must find out their ancestry—and he must trace as long a sequence of generations as he can, each in individual detail.

The method of sending out, to thousands of people, lists of questions to be answered and returned and analysed must yield to the method of what the Americans call the

THREE GREAT FOUNDERS OF EUGENICS

AUGUSTE COMTE

PROF. PATRICK GEDDES



JOHN STUART MILL

"field-worker," who goes out into the field of inquiry, visiting the families under study, and getting from them, by inquiry and personal observation, the precise details required. Then the relatives of the family must, in turn, be visited and studied at first-hand. Every man of science, every young student of science, realises at once that this is the only method of getting at the truth. Already it has yielded the most invaluable results, upon which eugenics must build here as elsewhere, and which our present exposition will recognise, even though this country is yet so far behind that the American work still awaits recognition, to say nothing of imitation.

The study of human heredity is, of course, the foundation of the foundations of eugenics, and we should not spend too much space upon it though we never left it. But to regard it as the whole, or anything like the whole, would be as serious an error as to suppose—with only too many enthusiasts—that we can "go right ahead" in our eugenic projects, without needing the guidance of genetics at every moment. On the contrary, it is already clear, as we shall see later, that certain eugenic projects, which seemed unquestionable and complete, must be wholly restated, or even abandoned, in the light of what the new study teaches.

Illuminating American Study of Heredity in Plants and Animals as well as Men

It is the old story, which every science illustrates. The facts of human heredity have never before been studied in the right way. When that right way is found, knowledge simply flows in upon us, and the stagnant pools which we thought to be knowledge are flooded clean away.

It remains to add that the experimental study of heredity in plants and animals is also being prosecuted in America, on a great scale, chiefly with the aid of Mr. Carnegie's money, along other and novel lines, too much neglected here. The American students, notably the distinguished botanist Macdougal, are showing how changes in environment may affect parents and their offspring, and how some of these changes are found to be transmitted according to Mendel's law.

The American work in heredity, both that of the Eugenics Record Office and that of the experimental botanists in Arizona and elsewhere, represents the utmost of human knowledge on these subjects. In America the opportunities, the funds, and the open-mindedness are available; and with the great exception of the school of Bateson we in this country are mostly trudging at random over ground which has been already found and charted and tilled by the great American school of biologists who are now laying the foundations of eugenics in "the solid ground of Nature."

Since the foregoing paragraphs were written, those who realise the fundamental importance of genetics have had the great satisfaction of hearing that an anonymous benefactor has founded a permanent chair at Cambridge, to be called the Balfour Chair of Genetics, in honour of Mr. A. J. Balfour, and his well-known interest in this subject. This will be the first chair, so named, in the world, but within a generation no university anywhere will be without its Chair of Genetics.

The Part Played in Eugenics by Study of Nervous Diseases

The *medical sciences*, as we have already seen, are part of the foundations of eugenics and we shall soon find that we can do without neither their principles nor their details. Toxicology, or the science of poisons, instructs us as to many of the "racial poisons," as we have agreed to call them; and neurology, the study of nervous disease, is no less necessary. There are three well-known forms of paralysis, for instance, of which one "infantile paralysis," is not transmitted to offspring; the second, "general paralysis," involves risk to all offspring; and the third, which is named after the English neurologist Sir William Gowers, is transmitted according to the Mendelian law some of the offspring being affected and others escaping. Obviously the duty of the Eugenist varies in these three cases and in such, and in a host besides, he cannot achieve his end unless he consults neurology at every moment.

The Part Played in Eugenics by the Study of Motherhood

Most notably must the Eugenist consult and employ the great medical science of *obstetrics*, or midwifery, including therein the study and care of the expectant mother her due nutrition, her protection from the racial poisons and from overwork, causing an undue strain upon her doubly taxed body, and leading frequently to the premature birth of her child. The influence of due care of expectant motherhood upon the life and health of babies has been proved overwhelmingly by every mode of first-hand inquiry; and it is deeply to be regretted that actuarial writers on this

subject have already announced their disagreement with what is so well known to the expert, and are thereby prejudicing the eugenic legislation for the protection of motherhood which at the present time is the most urgently necessary that can be named. But the case illustrates our present contention that the foundations of eugenics are manifold, and that, if we would avoid errors, we must ignore none of the sciences that bear upon the subject.

Psychology, closely allied to, but not usually included among, the medical sciences, is a necessary foundation of eugenics, for the Eugenist is dealing not with atoms, nor machines, but with men and women, who wish and will, and purpose and feel. The psychology of adolescence and the psychology of sex, including all the problems of sex-attraction, and of what Darwin taught us to call sexual selection, profoundly concern the Eugenist, who seeks to turn these forces to his account, and who cannot possibly control or direct what he does not first understand. Though psychology in this country is the study of the very few, there is no science more fascinating, more absolutely the "proper study of mankind," and in time it will take its due place in culture, and, above all, in the training and the argument of the Eugenist.

The Part Played in Eugenics by a Study of Anthropology

Already we can acclaim, at any rate, the "Social Psychology" of Dr. McDougall, the original and patient investigator who teaches psychology at Oxford, and who, in this notable and epoch-making book, already acknowledged by his compeers, has well and truly laid a necessary part of the eugenic foundation—above all, in teaching us to understand the instincts, of sex and of parenthood, upon which the possibility of eugenics must always depend.

Anthropology, especially that part of it which studies and compares the various types and races of man, is obviously fundamental to what may be called racial and inter-racial eugenics. We cannot appraise such events as the disproportionate increase of the black, compared with the white, population of South Africa, unless we have consulted anthropology as to the place of the two types in the human scale. According as anthropology reports of this race and that must we proceed in our legislation of and for the future. The impossible alternative would be to go by the shouts of the mob, by race prejudice, vested interests, existing custom, or the convenience of politicians in making those legislative decisions upon which, in such cases as this, the future of the world so evidently depends. In such crises, which will soon appear stupendous even to the dullest eyes, the Eugenist and the statesman can surely build upon no foundations but those of anthropology. The substitutes have been tried in every part of the world, and in every past age, when and where these questions of race and race have arisen; and wherever they have been tried they have been found wanting. Science now claims her place.

The Part Played in Eugenics by a Study of Sociology

Sociology, the science of society, including history in the great sense of the word, is evidently indispensable for eugenics. This noble science studies all the others in their social relation; sees the individual not only as individual but as citizen, member of a greater whole. If the Eugenist forgets society, and supposes that he has only to deal with disconnected and independent individuals, if he has no idea of, for instance, marriage as a social and a legal institution, he will certainly make proposals which, while excellent in themselves, will be nothing but disastrous or ridiculous when applied to the real world of human society. This is an error to which the Eugenist is evidently prone. He ascertains definitely the result of this, that, or the other union, as shown by such a science as genetics, and looks up from his specimens and genealogical tables to make demands as to the marriage of this person and the non-marriage of that, quite regardless of the fact that these persons are parts of a whole, and that, for instance, law and public opinion and "ways and means" and the Churches are all to be reckoned with.

The Part Played in Eugenics by the Study of Civics

Indeed, one of the best omens for the future of eugenics in this country, among many less welcome, is to be found in the definitely sociological attitude of Galton, and in the fact that it was the Sociological Society which persuaded him to come forward, after a long interval of years, and state the eugenic case for the ear of the thinking public. Like many other learners on that occasion, the present writer recalls it with solemn and enduring respect. It is one of the days that do not die, and its influence upon eugenics is only now beginning to manifest its full force.

Civics is a special branch of sociology, daily increasing in importance, which cannot fail to grow and flourish so long as Professor Patrick Geddes lives to be its champion. No one who has studied this distinguished author can deny his argument that the study of civics, and the prosecution of those ideals which civics recognises, must go hand in hand with eugenics. Eugenics cannot succeed, as Geddes shows, unless we have also a Eutopia—not Utopia, which is nowhere—but a "good place" for the products of our good breeding. To talk eugenics and countenance or ignore slums is a folly and an impertinence only one degree less outrageous than the sham eugenics—the latest *alias* of Mammon—which approves the slum as weeding out the unfit. In all such matters the civics of Professor Geddes and his followers is the necessary foundation for any eugenics that is to be more than a record of promise blighted. The Eugenist urges and proclaims the half-truth, too little recognised, that the people often make the slum; but if he does not also recognise the complementary half-truth that the slum makes the people, it is only because he is somewhat clumsy with his label, and has so glued it over his eyes that he cannot see.

The Need for a Cautious Use of the So-Called Science of Statistics

The "*science of statistics*" is not a science but a method, invaluable for the prosecution of the other sciences. But the method is no less treacherous than invaluable, and it cannot possibly be applied with success except to material which is itself valid and properly gathered. We have already observed how the American Eugenists are setting us an example in the collection of their data. When similar methods are employed in this country we may be able to make contributions of our own to the study of human genetics by the statistical method, the results of which hitherto, including those long ago obtained by the pioneer Galton himself, are now being called in question on every hand.

Great studies like education and politics are evidently involved in eugenics, but we have recognised them implicitly when we acknowledge psychology and sociology respectively. Similarly we have to recognise the importance of dietetics, or the science of nutrition, but that we have already done when we included physiology as one of the foundations of eugenics. We have lately learnt that exceedingly minute modifications of diet, even such an everyday diet as bread, may make an incalculable difference to the development of the individual; and evidently eugenics must pay heed to whatever this important and rapidly developing department of physiology has to teach. Similarly we have to recognise the great modern science of economics, which now replaces the "political economy" of the past; and we shall only too quickly see how disastrously economic facts and laws may interfere with eugenics, and almost make the "laws of Nature" of non-effect. But this great science we have also acknowledged, as it is evidently a department of sociology.

The History which is not a Science has no Place in Eugenics

Somewhat of the range of the foundations of eugenics will now be apparent, though we are not to suppose that the foregoing statement of them is complete, for that would be to commit the supreme crime against science of barring the door to future knowledge. But we cannot realise how much eugenics involves unless we deliberately pause a while to weigh the words which represent the great subdivisions of its substructure. For instance, we casually mentioned history as being included under sociology, and as thus contributing to the foundations of eugenics. But history, as that term is usually understood, contributes nothing to eugenics, is not a science, and would obviously be out of place in any work of science. Plainly what must here be meant is history in a different sense. Ruskin long ago pointed out that the so-called history which deals only with the visible government of a people is no more its real history than a catalogue of a man's wardrobe is his biography.

The History that is a Science is the Very Foundation of Eugenics

There must plainly be a kind of history which is also a science—a history which deals with the growth, development, maturity, death, division, and reproduction of a nation as of an individual; and if such history be not a foundation for eugenics, obviously nothing is. It is now becoming possible to adduce evidence which interprets the facts of accepted history in terms of eugenics, and which, above all, teaches us eugenic lessons for the present day. The problem of the nations of the future may thus be brought a stage nearer solution, if we approach it with the modern sciences, here reviewed, at our disposal, and with the new evidence which they enable us to extract from apparently meaningless or arbitrary historical events.

THE CLOUDS OF THE SUN

Revelations Arrived at by Direct Observation and by an Analysis of Sunlight

STORM-CLOUDS THAT RAIN MOLTEN METALS

The blazing disc we see when we look at the sun is not the body of the sun, but only the outer surface of the clouds which completely surround and cover it. This mantle of incandescent clouds, of unknown thickness, is called the photosphere, or "light-sphere." Within it is the central core, containing by far the greatest proportion of the total mass of the sun, though we cannot by any possibility see it. Outside the photosphere, and enveloping it completely, is a second mantle, of rosy colour, called the chromosphere, or "colour-sphere." This consists not of clouds, but of gases, especially of hydrogen, and is invisible except at times of eclipse or to an observer with the spectroscope. Outside the chromosphere, again, is a vast, mysterious, ever-varying system of radial streamers of light, extending outward to prodigious distances. This halo, hitherto seen only at eclipse, is known as the corona, or "crown." Reckoning from within outwards, therefore, we have the nucleus, the photosphere, the chromosphere, and the corona; and we shall consider them in that order.

The central nucleus, as we have seen in earlier chapters, is a mass of intensely heated gases under enormous pressure. The temperature and the pressure alike are quite inconceivable, and together are supposed to produce a condition for which laboratory experiments can show no analogy. The temperature is so high that even under the pressures to which they are there subjected these gases do not liquefy; and, enormous as the temperature is at the surface of the sun's globe, it must increase to an incomparably higher degree towards the centre. The pressure is such that the mixed gases become denser than water, attaining a density of 1·406; and inasmuch as the viscosity, or adhesive power, of gases is known to increase in proportion to the temperature, it is believed that the gaseous material of the sun's nucleus has a consistency somewhat like that of putty. Yet, with all this density and clinging stickiness, the sun's core never ceases to be gaseous. Though this state of things is barely imaginable, it is not on that account at all impossible. Yet it must be borne in mind that there neither has been, nor, so far as we know, is ever likely to be, any direct observation of the nucleus of the sun. All conclusions with regard to it are merely inferential.

The photosphere, or mantle of incandescent clouds, forming the visible surface of the sun, consists of actual clouds with a considerable likeness to those of the earth. As our clouds are formed by the condensation of vapour, by cooling, into minute droplets which float in the atmosphere, so the sun-clouds are formed by the condensation of metallic vapours, by cooling, into minute droplets and crystals, that float in a similar manner in the gaseous solar atmosphere. As our clouds do not in general extend over us in an unbroken roof, but are separated from one another and make a kind of pattern in the sky, so it is with the sun-clouds. They, too, give a distinct characteristic texture or pattern to the visible surface of the sun. As our clouds drift with the winds, are whirled in cyclones, and are drawn out into long streamers, so are the sun-clouds. And it is not unreasonable to believe that, just as our clouds fall in rain, so the clouds of the sun drop showers and cataracts of molten metal into the blazing abysses below. But whereas the clouds of our earthly atmosphere shine only by the reflected light of the sun, these solar clouds are self-luminous, and are, indeed, the very source of the sun's light by which we see.

The sun's surface is studied by means of telescopes constructed in such a way as to

reduce the light to a degree comfortable for the eye. It is also studied by means of photography in conjunction with telescopes. When seen by either of these means, the photosphere presents a remarkably granular appearance. Innumerable bright, irregular grains or flecks are closely strewn upon a darker background, and are irregularly grouped in clusters and curved lines. The general impression has been compared to that given by snowflakes scattered on a grey cloth. Under the highest telescopic power and in exceptionally clear states of the earth's atmosphere, these grains or flecks have been seen to consist of yet smaller granules closely grouped together. The grains and granules, having diameters, roughly speaking, of 1000 and 100 miles respectively, are the incandescent clouds of the sun. Probably the grains and granules thus seen are the outer ends of vertical columns of cloud; for where the solar atmosphere is much perturbed, as in the neighbourhood of sunspots, the grains are drawn out into long, irregular, parallel streaks and filaments.

Some of the Changes which Photography Registers in the Sun

A curious fact about the granular structure of the sun's visible surface has been revealed by photography. Even in a perfect photograph this granulation is sharply defined only over limited areas, separated from one another by an irregular network of patches in which the solar surface appears misty, confused, and non-granulated, very much as if it had been out of focus, or as if the photographic plate had in some other way been blurred by a network of streaks. This "photospheric reticulation" (*i.e.*, network of the photosphere) changes in such a way that although two photographs taken within a few moments of one another show the same reticulation, the form of the network is found to have changed if an hour or more has elapsed between the first photograph and the second. This local indistinctness, obliterating the granular structure, is probably due to violent motions of the sun's atmosphere, preventing any clear vision through the regions in which they may happen to occur; and the changes of reticulation will in that case be due to the motion of atmospheric storms across the surface of the sun. "The simple fact is," says Professor Young, "that we are looking down upon the granules and other features of the sun's surface, not through an atmosphere shallow, cool, and quiet like the earth's, but through an envelope of matter, partly gaseous and partly, perhaps, pulverulent or smoke-like, many thousand miles in depth, and always most profoundly and violently agitated."

To this smoky character of the photospheric atmosphere is ascribed the comparative darkness of the background against which the incandescent clouds are seen. The metals rising from the interior in the form of vapour, in mighty ascending currents, are first condensed into incandescent droplets or crystals, and so give rise to the luminous clouds; and then, becoming further cooled as they radiate their heat into space, lose their incandescence and form a smoke or fog which sinks downward between the clouds, until it reaches a level at which the temperature is sufficient to convert it again into vapours of the metals.

Why the Light of the Sun Appears to us to be More Brilliant in the Middle

The same smoke, pervading the atmosphere around and above the brilliant clouds, accounts for the remarkable absorption of light at the edge of the sun's disc, or, as it is usually called, at the "limb" of the sun. It is obvious that, since the shining surface of the sun is a sphere, the light which comes to us from near the edge of the apparent disc must pass through a greater thickness of the overlying solar atmosphere than light which comes to us from the centre of the disc. From the diminution of the sun's brilliancy towards its edge, which is very evident when the sun is viewed through a smoked glass or through an evening haze, it is reasonable to infer that the atmosphere of the sun intercepts a considerable proportion of his light.

By means of the spectroscope, it is possible to determine the chemical elements present in the incandescent clouds and in the solar atmosphere in which they float.

The Colours that Mark the Limits of Human Vision

A description of this instrument in its various forms, and of the results gained by it, appears in another part of this work, and need not be repeated here. It is enough if we understand that white light consists of a blend of lights of all colours, from red, through orange, yellow, green, and blue, to violet, with every intermediate shade of colour; that every particular shade of colour is given by light-waves of a definite length, the waves of red light being the longest and those of violet light the shortest; and that there is an indefinitely extended series of wave-lengths longer than those

of red light, and similarly an indefinitely extended series of wave-lengths shorter than those of violet light. The range of colour from red to violet marks, not the limit of the longest and shortest light-waves, but the limit, in each direction, of human vision.

How White Light is Broken up by the Spectroscope

Now if, by means of the spectroscope, a ray of white light is passed through a narrow vertical slit, in order to give it the definite shape of a thin ribbon stretched horizontally with its edges vertical, and if it then passes through a prism of glass, the innumerable coloured lights constituting the white light are separated out by the prism, according to their wave-lengths. So the light which entered the prism as a single white ribbon leaves it as a series of innumerable divergent coloured ribbons. But if the ribbon of light entering the prism, instead of being white and containing all wave-lengths, consists of light containing, let us say, only three or four definite wave-lengths, it will emerge from the prism as three or four definite divergent ribbons. In the spectroscope the ends of these ribbons of light come into view side by side as a row of vertical coloured lines, or coloured images of the slit, extending from deep red at the left hand to violet at the right. In the spectrum of white light these vertical coloured lines, however narrow the slit is made, touch and overlap, forming a continuous spectrum. We may compare the spectrum to a fence of vertical laths. In a continuous spectrum the laths touch and overlap. In other spectra, however, there are laths, many or few, here and there; and as every part of the fence is accurately mapped, the spectrum produced by any special source of light can be definitely recognised.

The Use of the Different Spectra in Examining the Sun

There are certain principles, of great importance, which reveal the *nature* of a distant source of light. Thus, a continuous spectrum, comparable to a fence in which all the laths are present, comes from an incandescent solid, or from an incandescent liquid, or from an incandescent gas under great pressure; that is to say, these bodies, when heated so as to become self-luminous, give out light of all wave-lengths within the range of vision. A discontinuous spectrum, on the other hand, comparable to a fence from which many or most of the laths are absent, comes from an incandescent gas that is not under great pressure, or from a mixture of such gases. That is to say, any material in the gaseous condition and uncompressed, whether it be one of the bodies we know on earth as a gas, or whether it be a metal heated to such a degree as to become a luminous vapour, gives out only certain lights of definite wave-lengths, and so produces a spectrum characteristic of that particular gas or vapour. This spectrum consists of bright lines and bright bands, at certain definite parts of the whole range of the spectrum.

But besides the continuous spectrum and the discontinuous spectrum of bright lines and bands, there is a third kind of spectrum, which for the study of the chemistry of the sun is the most important of the three. This is a discontinuous spectrum of black lines, superimposed upon the continuous spectrum of all the colours. It depends upon the remarkable fact that any gas, interposed between an incandescent source of light and the spectroscope, absorbs exactly those kinds of light that would constitute its own bright-line spectrum if itself were to be incandescent. The intervening non-luminous gas throws black lines upon the spectrum, exactly in the places where it would throw bright lines if itself were the source of light.

How the Story of the Chemistry of the Sun is Read

In consequence of this principle, it is possible to identify the comparatively non-luminous gases and metallic vapours present in the atmosphere of the sun, around and above the clouds of the photosphere. Obviously, these clouds, being incandescent masses of liquid droplets and solid crystals, give a continuous spectrum, but each of the intervening gases and metallic vapours in the solar atmosphere absorbs light of certain definite wave-lengths. The solar spectrum, therefore, as we receive it, is a continuous spectrum crossed by a vast number of black lines. These black lines tell the story of the chemistry of the sun's atmosphere.

We have spoken of these intervening gases as *comparatively* non-luminous, because they are non-luminous only in comparison with the fierce glow of the incandescent clouds. They are actually luminous, though in a far lower degree. This is beautifully seen in eclipses of the sun, when the solar atmosphere throws for a brief moment its own bright-line spectrum, before the moon, which has already eclipsed the sun's disc, eclipses his atmosphere also. For that brief moment the sun's atmosphere is seen to act, not as a veil throwing

a black-line spectrum, but as a source of light throwing a bright-line spectrum.

So it is that by means of spectroscopic analysis the photosphere, including not only the incandescent clouds but also the atmosphere in which they float, has been shown to contain a large number of the elements familiar to us on earth. It is hardly worth while to lay much emphasis on the failure to discover any particular element in this way, as the list of those definitely determined is continually being enlarged. Yet the apparent absence from the photosphere of some of our commonest terrestrial elements, such as nitrogen, chlorine, sulphur, etc., is so remarkable as to need some explanation.

Does the Fierce Heat of the Sun Break Up What We Call Elements?

The matter has been much debated, and two theories are at present maintained to account for their omission. One is based upon the fact that certain elements are known, under laboratory conditions, to give different spectra according as they are subjected to different treatment; and it is reasonably enough suggested that in the solar heat the spectra of some of our familiar elements may be so altered as to escape recognition. The other view, originated by Sir Norman Lockyer, is to the effect that these substances which the spectroscope fails to find in the solar atmosphere are not really elementary substances, but are there split up into their constituent elements, having separate spectra which are unknown to us.

We have seen that the visible surface of the sun has a granular appearance, caused by the bright clouds floating in the smoky atmosphere. Nothing is known as to the lower limits of this mantle of clouds, or photosphere, nor whether it is separated from the sun's nucleus by any definite surface. The upper or outer surface of the photosphere is, however, very definite, as may be seen from the sharply cut edge of the sun's disc.

Strange Appearances on the Sun's Atmospheric Covering, or Photosphere

Yet there are irregularities of two kinds on the surface of the photosphere, both of great interest. In some parts the luminous clouds, which generally lie in a more or less level plain, rise to form great mountains and ridges of incandescent cloud-stuff, appearing to the observer as patches and streaks greatly exceeding in brightness the surrounding regions. In other parts the brilliant surface of the photosphere may be seen to be torn apart, or deeply depressed in the smoky atmosphere, so as to produce patches that are quite dark as compared with the surrounding surface. The patches of brightness are known as faculæ—that is to say, "little torches"; the dark patches are known as sunspots. (See page 1743.)

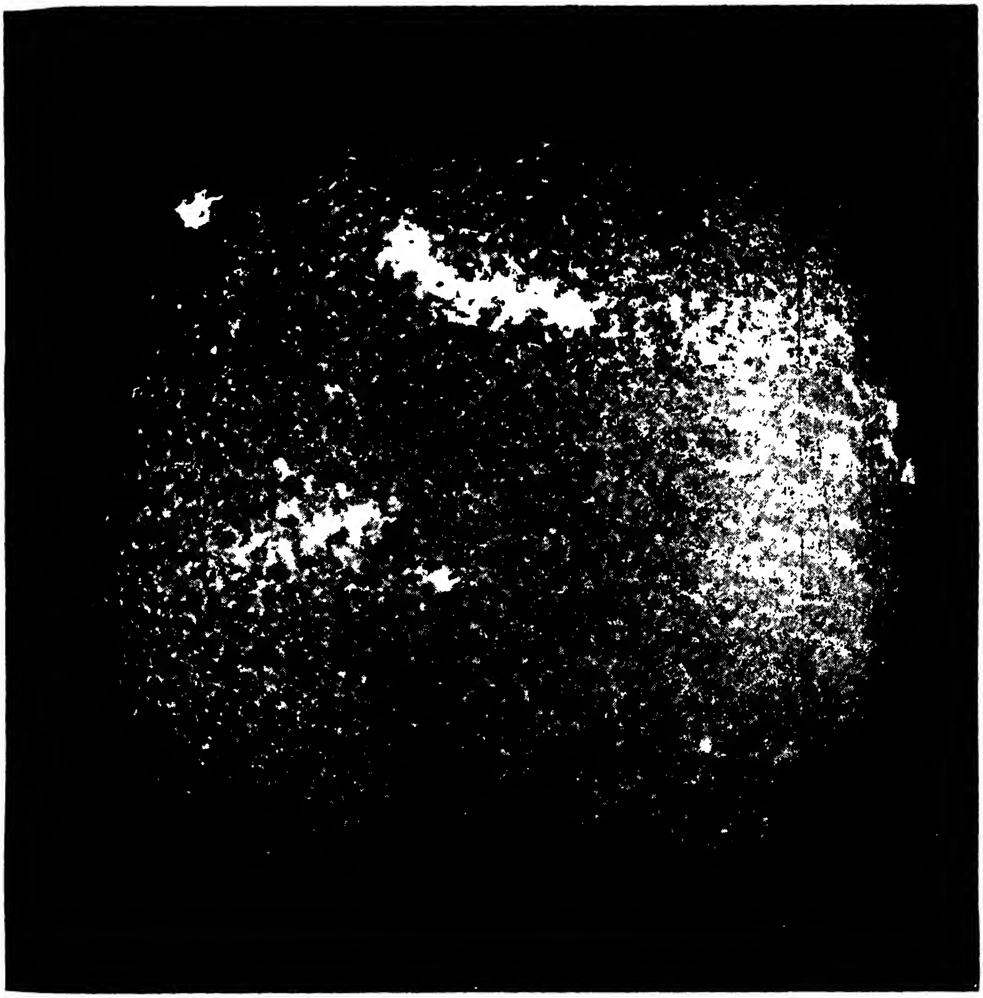
Both of these features may be well seen by a simple device. A telescope mounted on a tripod is directed to the sun, but the observer does not look through the telescope. The image of the sun is instead projected by the telescope on to a white card placed a few inches from the eye-piece and perpendicular to the tube of the telescope. The card may be attached to the telescope by means of a wire frame, and it is well to pass the other end of the telescope through a circular hole cut to fit it in another card, so as to screen the image from all direct light of the sun except the rays that pass through the telescope. The image of the sun thus obtained, say from nine to twelve inches in diameter, will not show clearly the texture of the photosphere, but it shows beautifully the faculæ and sunspots, and the diminution of the sun's light towards the edge of his disc.

The Flaring Brightness of the Sun's Surface that Makes Other Brightness Dark

Spectroscopic methods have shown that the faculæ are formed in every part of the sun's surface, though they are far less numerous towards the Poles than elsewhere, and are especially numerous in the vicinity of sunspots. However, to an observer with a telescope, or in the image thrown on a card in the manner described above, faculæ are visible in the regions of diminished illumination towards the edge of the disc, but are invisible in the more brilliant central regions of the image. The reason for this difference is found in the fact that though they appear only like little patches of extra brilliancy, the faculæ are vast elevations of the photospheric cloud surface, often many thousand miles in diameter, and rising to great heights in the solar atmosphere. This atmosphere, as we have seen, absorbs a considerable portion of the light from the incandescent clouds, but does so to a very much greater degree towards the edge of the disc than towards its centre, because light coming from the edge has to penetrate a much greater thickness of atmosphere than light coming from the centre. Inasmuch as the incandescent faculæ rise far through the solar atmosphere, and may in some cases even extend above it, their light suffers little, or in extreme cases no, diminution from the

atmospheric veil, and is consequently nearly or quite as bright towards the edge of the sun's disc as it is in the central area of the disc. Towards the edge of the disc, however, the general surface of the sun, forming the background against which they are seen, is far less brilliant, and the faculæ are consequently far more conspicuous than in the centre of the disc, where, owing to the comparative thinness of the atmospheric veil, there is no great difference in brightness between the faculæ and their surroundings.

That the faculæ are eminences rising far above the general surface of the photosphere is proved by the sight of them sometimes in profile at the edge of the sun's disc, where they appear as minute and very brilliant projections of the outline. The spectroscopic evidence to the same effect is very striking, and has been made the means of showing the existence of faculæ in the central regions of the disc. It will be remembered that the gases of the solar atmosphere, though enormously hot according to all terrestrial standards, are relatively cool as compared with the photospheric clouds which lie below them, and therefore act spectroscopically, not as themselves an incandescent source of light producing a bright-line spectrum, but as gases interposed between the source of light and the spectroscope, producing a spectrum of black lines. From certain patches of the sun's surface, however—namely, from the faculæ—these gases and metallic vapours, or some of them, throw



THE SURFACE OF THE SUN WITH THE PATCHES OF EXCEPTIONAL BRIGHTNESS

This photograph was taken at the Yerkes Observatory on April 27, 1903

a bright-line instead of a black-line spectrum, proving that in such places the hotter substances from below have been projected upwards through the comparatively cooler atmosphere.

"Suppose, for instance," says Sir Robert Ball, "a prominence consisting of a vast mass of glowing calcium vapour is projected to such an elevation in the sun's atmosphere that the brilliance which the incandescent vapour pours into the calcium lines more than compensates for the absorption due to the cooler calcium vapour outside, then we have what is called a reversal of those particular spectral lines. Sometimes the singular spectacle is presented which is known to spectroscopists as a double reversal; in this case the ordinary dark line is filled with a rather broad band of luminosity, and down the centre of the bright band a fine dark line is found to be inserted. In this case we interpret the double reversal to be an indication of the presence of a volume of glowing gas overlaid by a not very copious atmosphere of the same gas in a cool state."

Sunspots the Most Striking Feature on the Surface of the Sun

Photographs taken of the sun by means of the spectro-heliograph, which admits light belonging only to one part of the spectrum, show faculæ all over the disc of the sun; and from a series of photographs of this kind it has been shown that in general the faculæ change their shape very slowly, and often remain unaltered from day to day. In the vicinity of sunspots, however, they are subject to violent changes.

Sunspots are in several respects the most striking features of the surface of the sun. They are sometimes so large as to be seen easily with the unassisted eye, and have therefore been known for many centuries, though until comparatively recently they were taken to be planets passing between the earth and the sun. It was not until the advent of the telescope early in the seventeenth century that their true nature as dark spots on the solar surface was clearly recognised. They have been much studied during the last fifty years, but astronomers are not yet fully agreed with regard to their nature and causes.

A typical sunspot has the appearance of a more or less circular aperture in the incandescent photosphere. At its centre is a very dark area, like the mouth of a pit, called the umbra; and round this central black spot is a moderately dark border, called the penumbra, consisting of irregular, wavy streamers of cloud grouped more or less radially. The umbra is not really dark, but is actually very brilliant; it appears dark only in contrast to the surrounding regions of the blazing photosphere. Its area is often pierced by a few small round spots much darker than itself, and these are supposed to represent pits penetrating to the deeper abysses of the sun. The penumbra apparently consists of incandescent clouds drifting into the umbra, and seems brighter at its inner edge, next the umbra, than at its outer rim, next the unbroken surface of the photosphere. The tips of the clouds of the penumbra break off and melt away in the umbra.

Are Sunspots Atmospheric Whirlpools Around Holes in the Sun's Cloud-Mantle?

Sunspots are not by any means always circular, but assume a great variety of forms, some of them extremely irregular. The faculæ, or "little torches," described above, are numerous in their neighbourhood, indicating, like the sunspots themselves, violent perturbations of the solar atmosphere. Individual spots arise as minute specks, grow in size, change their shapes, often divide into two or more spots thus forming a group, and, after persisting for a few days, weeks, or months, finally disappear. Most of them last about eight or ten weeks, but sunspots have been known to remain for a year, and even for eighteen months.

These spots are plainly depressions in the surface of the photosphere. A circular sunspot, as it travels westward with the solar surface (see page 1739), becomes, as we should expect, narrower from side to side as it is fore-shortened in its journey away from us towards the edge of the sun; and at the same time, as we should expect from a cup-shaped depression, the penumbra on the side of the spot towards the centre of the sun's disc becomes narrower, until it may even disappear altogether.

The Size and Distribution of Sunspots Over the Sun's Surface

Sunspots vary greatly in size, the largest on record having a diameter of 143,000 miles. This, however, is very exceptional, and a sunspot having a diameter of 20,000 miles is considered a fairly large one.

Sunspots are not equally distributed over the surface of the sun, but occur chiefly in two zones, one in the northern hemisphere and the other in the southern hemisphere, at equal distances from the equator. The Poles and the equator are nearly free from spots, and by far the greater number

appear between the latitudes of 10 degrees and 35 degrees north and south. Sometimes the northern hemisphere, and at other times the southern, is more affected by spots than the other; for example, a period of forty years has been known to pass without any sunspots appearing on the northern hemisphere at all.

Sunspots have movements of their own; thus, a small proportion of them rotate in one direction or in the other, and the two spots formed by the division of a single spot are sometimes seen to fly apart with great velocity. In general, however, the sunspots move with the surface of the sun, and are consequently useful in determining the direction of the solar axis and the speed of the sun's rotation. By observations of the movements of sunspots the remarkable fact was discovered that while a point on the sun's equator makes a complete revolution in little over twenty-four days, a point at 50 degrees north latitude takes over twenty-seven days for one revolution. That is to say, the sun, or at least the photosphere, does not rotate in one piece as a solid body would do, but the equatorial regions rotate considerably faster than the regions about the Poles. Various theories have been brought forward to account for this fact, but none of them is altogether satisfactory.

Some Apparent Influences of Sunspots on the Atmospheric Conditions of the Earth

The frequency of sunspots is greater in one year than in another; and it has been definitely ascertained that the times when there are fewest sunspots and the times when there are most sunspots alternate with considerable regularity and at fairly constant intervals. It appears that the average interval between one time of maximum sunspot activity and the next is rather over eleven years. In this period about six and a half years show declining activity and the following four and a half years show increasing activity. The periodic rise and fall of the frequency of sunspots is unquestionably related to a periodic increase and decrease of disturbances in the magnetism of the earth, as shown, for instance, in displays of the aurora borealis.

But it is not so certain that a clear connection can be made out between the periods of sunspot activity, on the one hand, and the condition of our weather, the value of our crops, and the state of our trade, on the other hand. A great deal of ingenuity has been devoted to showing a connection of that kind between solar changes and terrestrial affairs. There is no reason to regard such a connection as impossible or even improbable; and any positive knowledge, for instance, of the sun's influence on credit would be highly valuable. Moreover, men of great authority in the scientific world have supported the theory. But others, with not less authority, have hitherto rejected it.

The Arguments For and Against the Whirlpool Theory of Sunspots

The nature and causes of sunspots are not yet fully understood. Many elaborate theories have attempted to account for their origin, but of these there remain only two which at present receive any considerable support. One, brought forward by Faye, regards a sunspot as caused by a vast vortical movement in the sun's atmosphere, of the same kind as our whirlwinds and cyclones, only on a prodigiously larger scale. It is supposed that these vortical whirls, as may be seen in any whirlpool set up by an eddy in a stream, create conical tunnels downward into the mass of the photosphere, and that the incandescent clouds surrounding them are sucked down into these cavities, thus producing the dark depression known as the umbra, and also the penumbra of self-luminous clouds streaming inwards and downwards into the abyss. This theory explains most of the facts well enough, but it is met by one objection that appears fatal to it. Only two or three sunspots in a hundred show the appearance of vortical movement, which, whenever it is present, cannot fail to be seen by the direction of the cloud streamers in the penumbra, as well as by the rotation of the entire spot.

Other Suggested Explanations in an Unended and Baffling Controversy

The other theory, originated by Secchi, regards the sunspots as formed by masses of metallic vapours which, after being thrown up by eruptions in the sun's surface, have become relatively cool in the upper regions of the atmosphere, and then, descending upon the surface of incandescent clouds, have formed the depressions in the luminous surface we know as sunspots. This theory is favoured by Professor Young. "It may be," he says, "that the spots are depressions in the photospheric level, caused not directly by the pressure of the erupted materials from above, but by the *diminution of upward pressure* from below, in consequence of eruptions in the neighbourhood, the spots thus being, so to speak, *sinks* in the photosphere." Possibly it is safest to suppose that no simple theory will ever account for these very complex phenomena.

AN ATLANTIC TIDAL WAVE CRASHING OVER A SOUTH AMERICAN BREAKWATER

This tidal wave broke with such force upon the long breakwater at Rio de Janeiro that the water shot upwards to a great height. The conical mass dividing the wave is the Sugarloaf Mountain which overhangs the harbour.

THE TRAVEL OF THE WATERS

The Plunging Sea Draws Backward from the Land Her Moon-led Waters White

THE TIDES AND CURRENTS OF THE SEA

The sea bares her bosom not only to the moon but to the sun, not only to balmy breezes but to howling hurricanes, not only to summer zephyrs but to winter tempests, and accordingly the sea's temperature varies from place to place and from time to time. Yet, owing to the great capacity of water for heat, the surface temperature of the sea at any place is comparatively constant.

Between day and night, the average range of surface temperature is only 1 degree, and between summer and winter, unless there be seasonal variation in currents, there is a range of only 5 degrees to 10 degrees Fahr. In the tropical zone, the surface of the sea never falls below a temperature of 80 degrees Fahr. In the Red Sea, the surface temperature varies in its average summer and winter temperature by only about 10 degrees.

The temperature of deep-sea water, though following other laws, is also very stationary. Deep water is always cold, even when the surface water is warm, except in an enclosed sea. At a depth of 300 or 400 fathoms, the water of unenclosed seas has a temperature of 40 degrees Fahr., or less. Five-sixths of the water of the oceans has a temperature below 40 degrees Fahr. The low temperature of the deep seas is due to currents of cold water from the Polar regions. Even as there are currents of hot air flowing in the upper atmosphere from the equatorial regions towards the Polar regions, and currents of cold air flowing in the lower atmosphere from the Polar regions to the equatorial regions, so in the ocean there are cold currents flowing along the bottom of the sea from the Polar regions to the equatorial regions, and warm currents flowing along the surface of the sea from the equatorial regions to the Polar regions. In the southern hemisphere the cold water runs northward along the ocean floor without impediment; in the northern hemisphere the cold water has access only by narrow channels to the south, but in both cases there is a constant current of cold water along the ocean floor towards the equator.

Bonney gives the following little simple experiment (first contrived by J. F. Campbell) to illustrate the circulation of cold and hot water in the ocean:

"Take a small glass tank such as a common aquarium, and fill it with water. On the top of a piece of black rock, a few cubic inches in volume, sprinkle some cochineal, and put this close to one end of the tank, introducing it into the water so carefully and gently as not to disturb the colouring matter. Then fix a good convex lens in such a position that the rays of the sun are brought to a focus upon the piece of rock. At the same time place on the water at the opposite end a lump of ice, and upon this pour a small quantity of milk. As the rock is heated, the surrounding water, which is becoming stained by the cochineal, is warmed. It expands, and a red cloud mounts upwards. But at the other end of the tank the water, which is rendered slightly turbid by the milk, is chilled by contact with the floating ice, and so a whitish cloud sinks downwards. Presently the former begins to drift along the surface towards the ice, the latter along the bottom towards the heated rock, and thus a system of oceanic circulation is established."

In the case of enclosed seas, the cold currents are excluded, and so the bottom water keeps at a higher temperature. The Red Sea, for instance, which on the surface has an average summer temperature of 85 degrees Fahr., and an average winter temperature of 75 degrees Fahr., has a

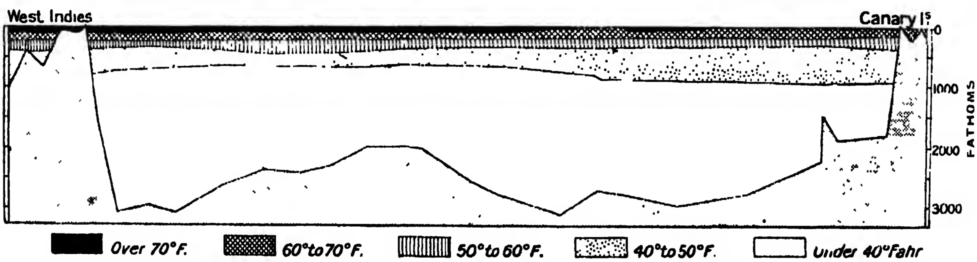
summer and winter temperature of 70 degrees Fahr. at a depth of 200 fathoms, and that temperature is maintained right down to its bottom. The Indian Ocean, just outside, unprotected from cold currents, shows a temperature of 37 degrees Fahr. at the same depth.

The constant circulation in the sea of cold, deep water from the Poles to the equator, and of hot surface water from the equator to the Poles, constitutes the "trades" and "anti-trades," so to speak, of the sea. But, besides these great voluminous circulatory currents, there are numerous other surface currents, mostly due, as has been said in a previous chapter, to wind. The wind pushes the surface water of the sea before it as the squeegee pushes the mud off the surface of the London streets. By such wind-currents, nuts, and beans, and seed—flotsam and jetsam of all kinds—are carried from the West Indies to the shores of Iceland, or Ireland, or Norway. The Great Labrador Current, driven by the northerly wind, brings the icebergs to Newfoundland; and the Great Banks of Newfoundland are probably built up of stones and mud transported by icebergs and deposited as the icebergs have melted. The south-east trade wind blowing off-shore in the Bight of Panama produces the cool Peru Current, which, sweeping southward past the Galapagos Islands, gives a more temperate climate than that of any other equatorial land. A cold current like the Great Labrador Current flows south through the Behring Straits.

The anti-trades of the Southern Ocean (in the so-called Roaring Forties) cause a great surface current in an easterly direction round the world. On the very day on which these words are written, the following notice appears in the newspapers: "A life-buoy inscribed s.s. 'Waratah,' and covered with barnacles, has been found at Waiuku, on the west coast of New Zealand." The "Waratah" left Durban for Cape Town on July 26, 1909, but never reached her destination, and was supposed to have capsized in a storm. The distance from Cape Town to the west coast of New Zealand is over 8000 miles, so that the life-buoy must have drifted eastwards at an average speed of nine or ten miles a day. Probably it was the Roaring Forties that carried along this relic of the ill-fated ship.

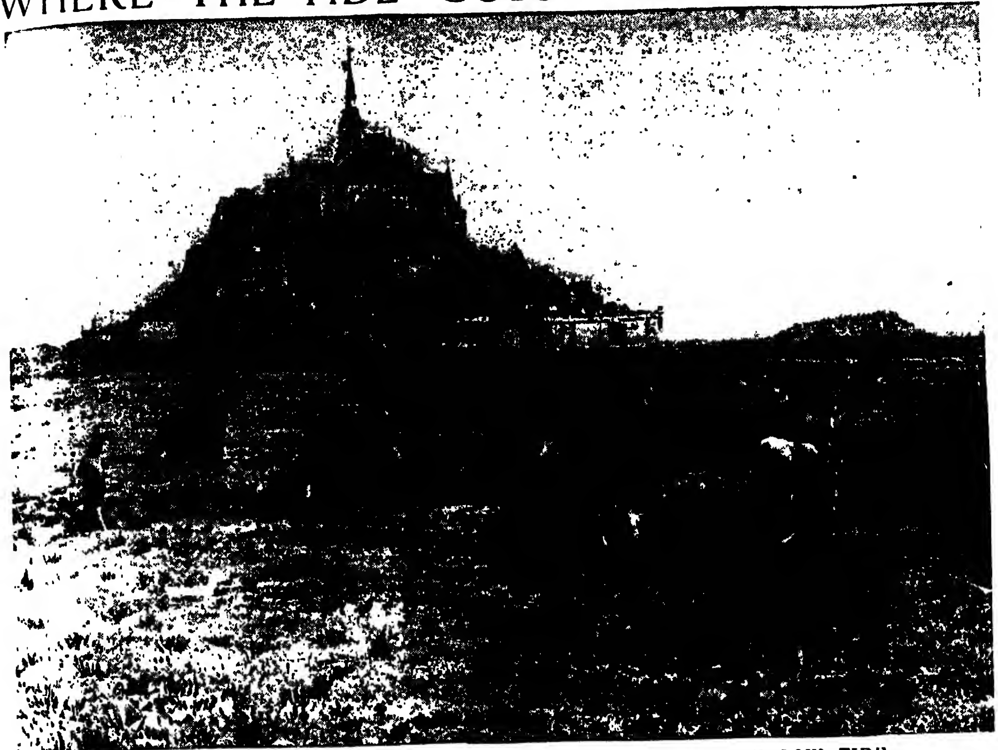
But the best-known current is that remarkable drift known as the Gulf Stream. The Gulf of Mexico is flooded with a current of warm water that sweeps into it from the South American coast through the Caribbean Sea. Out of the Gulf there issues, between the Peninsula of Florida on one side and Cuba and the Bahamas on the other, a mighty volume of blue, warm salt water—a great sea-river forty or fifty miles wide, about 200 fathoms deep, and flowing with a velocity of three and a half to five miles an hour. The current has been calculated to contain more than two thousand times the quantity of water discharged by the Mississippi. Its temperature off Sandy Hook is 75 degrees Fahr. In the first place it flows northward close to the North American coast, but soon it comes into the clutches of the south-westerly winds, and is carried eastward across the Atlantic, spreading out and slackening its speed as it proceeds. As it crosses the Atlantic, it divides into three currents, one going towards Iceland, one curving down past Spain, and one flowing past the west coast of Ireland and Scotland, and reaching even the west coast of Norway. The wind which brings this current is naturally warmed and wetted by it; and the warm, wet wind greatly modifies the climate of the lands it reaches, as we shall explain more fully when we come to speak of climate.

It has been estimated that the total quantity of heat transferred per day from the equatorial regions amounts to at least 20 per cent of the whole heat received from the sun by the entire area of the North Atlantic. "The total warmth of

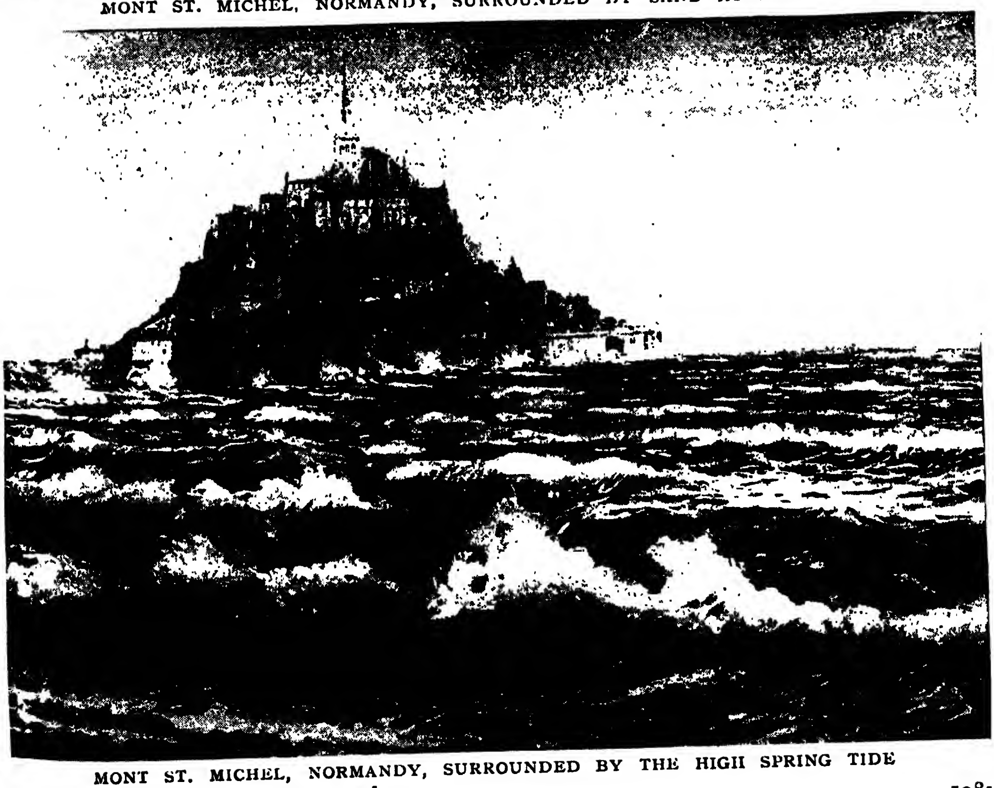


A SECTION ACROSS THE ATLANTIC, SHOWING THE TEMPERATURE AT DIFFERENT DEPTHS

WHERE THE TIDE GOES OUT FOR MILES



MONT ST. MICHEL, NORMANDY, SURROUNDED BY SAND AT LOW TIDE



MONT ST. MICHEL, NORMANDY, SURROUNDED BY THE HIGH SPRING TIDE

the current would suffice, if it were centred in a single point, to fuse mountains of iron and cause a river of metal as mighty as the Mississippi to flow forth. It would also suffice to raise from a winter to a constant summer temperature the whole column of air which rests on France and the British Isles."

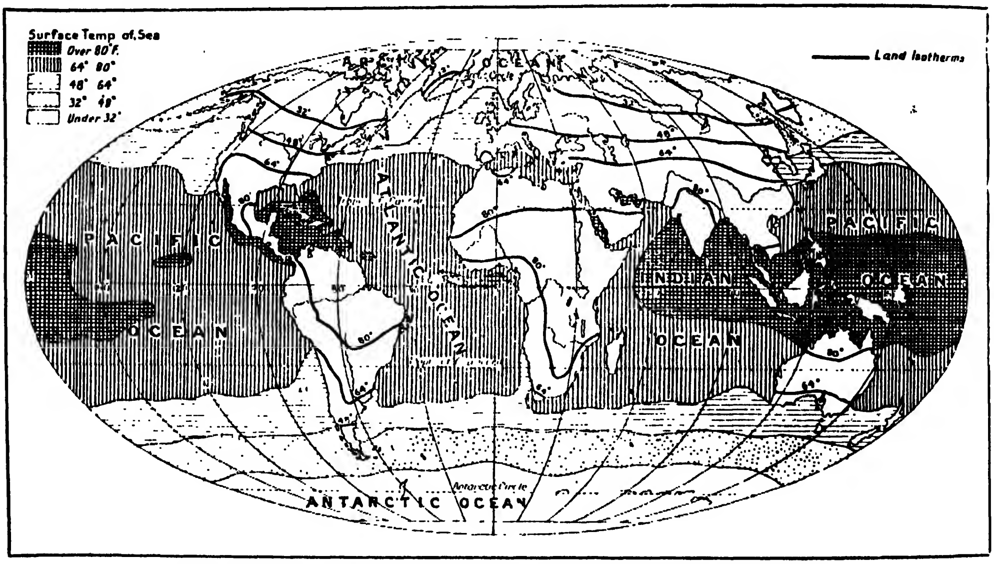
Most of the currents are caused by winds, but perhaps it is a mistake to trace each current to a particular wind. Rather the ocean currents are a complex movement due to all the atmospheric currents, and modified, like the winds, by the rotation of the earth, by the interference of land masses, and by other factors.

Besides currents caused by heat and cold and by wind, there are also currents caused through rapid evaporation of water, with consequent increase of saltness. The Red Sea, for instance, is lowered ten to twenty-five feet a year by evaporation, and the loss is replaced by a current of fresher water from the Indian Ocean; and at the same time a deep undercurrent of excessively salt water flows from the Red Sea to the Indian Ocean. The Mediterranean, similarly lowered by evaporation, receives a current of fresh water from the Atlantic, and returns to the Atlantic an undercurrent of excessively salt water.

Currents are also caused by the reverse process by the excessive addition of fresh water, with dilution of the salt contents. Thus the Don, the Danube, and other great rivers pour so much fresh water into the Black Sea that it contains only 2 per cent. of salts, and stands about two feet higher than the Mediterranean. The result is that a current of the diluted sea-water flows into the Mediterranean from the Black Sea, and an undercurrent of salter water flows from the Mediterranean into the Black Sea.

Few natural phenomena make such an appeal to the imagination as the tides. Their surge and thunder bear worthy witness to that mighty force that holds the earth and its sister planets in their orbits round the sun. The earth is tethered to the sun, and the moon tethered to the earth, and all three are tugging at their tethers, but the hard crust of the earth hardly yields to the strain, and only the sea, pulled up into a great tidal bulge, as it passes the moon, gives testimony to the tension. No sign does the silent earth, no sign do the tacit stars give of the great bondage; but the surging, singing tides testify to the tug of the tether—to "the subtle, secret, unseen bonds that make a million systems one."

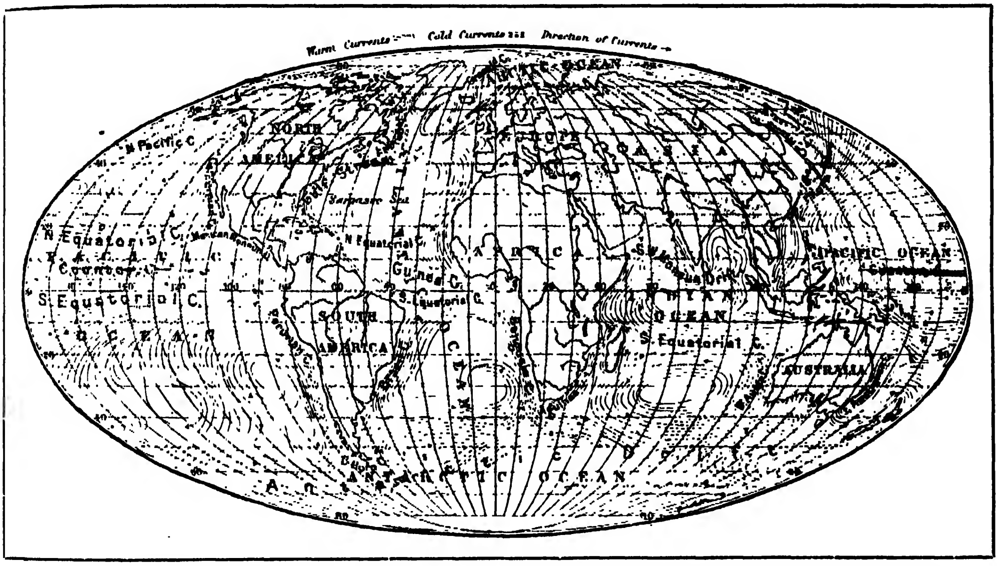
The man in the street usually gives the moon the whole credit for the tides, but this is not correct; the sun also plays a part, and a not unimportant part, in the tidal excursions of the sea. The moon, however, has about twice the tidal force of the sun; and so if they happen to pull to any degree against each other, it is the moon's tidal force that prevails. Let us look for a moment at the



THE SURFACE TEMPERATURES OF THE OCEANS OF THE WORLD

direction of the pull of sun and moon with reference to the tides and to each other.

The moon goes round the earth about once in twenty-eight days, and every day it is about fifty minutes later in rising. If, accordingly, the moon reaches its zenith at twelve one day, when the sun is also in its zenith, it will reach its zenith next day fifty minutes behind the sun, and next day a hundred minutes behind the sun, and next day one hundred and fifty minutes behind the sun, till eventually, just when the moon has finished a course of twenty-eight days it falls back in line with the sun again, and both sun and moon are again in the zenith together. Once each lunar month sun and moon are in the zenith together, and between times they diverge to all degrees till



THE COURSE OF THE WARM AND COLD CURRENTS IN THE OCEANS OF THE WORLD

at full moon the moon is exactly opposite the sun.

Now consider the effect of the relative positions of sun and moon. Theoretically when the sun is right overhead in the zenith it is solar full tide, and likewise when the moon is right overhead in the zenith it is full lunar tide. Suppose, then, they both are in the zenith together, as occurs at new moon, then there will be full lunar tide and full solar tide together, and therefore we have a specially high tide. The high tide at new moon is known as a *spring* tide.

Suppose, next, that the moon is in its zenith when the sun is exactly opposite at the other side (such a position as occurs at full moon), then on the moon side of the earth we will have full lunar tide, which is also high tide, and is also a spring tide.

Suppose, finally, that the moon reaches its zenith when the sun is a quarter way round the world and therefore at right angles to it (such a position as occurs both at new half-moon and at old half-moon), then the pull of the sun will partly neutralise the pull of the moon, and we will have a lesser tide, known as a neap tide.

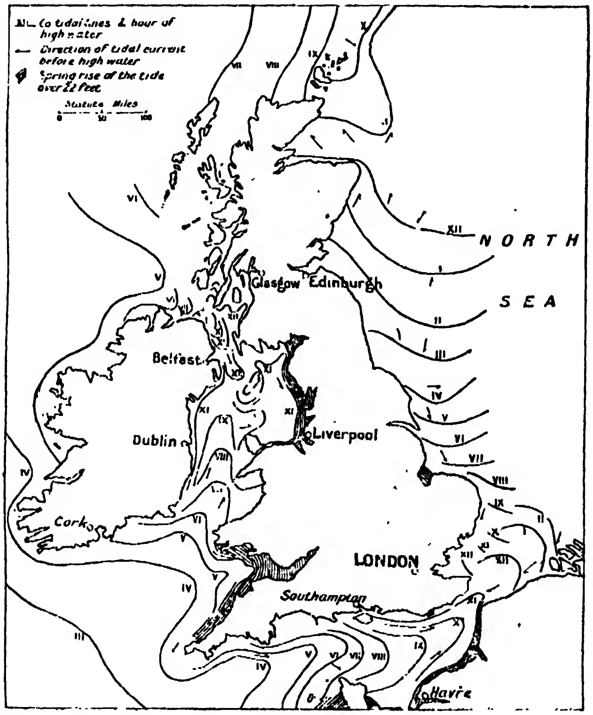
All this is pretty evident, but it may be asked how is it that there are two full tides in the twenty-four hours even when the moon and sun are not opposite each other ?

The reason simply is that each full lunar tide implies and necessitates a tide on the other side of the earth as well as on its own side. To understand this is not quite easy, but it is essentially a matter of differential attraction. The great law of gravitation enunciates the principle that bodies are attracted by other bodies in the inverse ratio of the square of their distance from each other. Thus a body A and a body B two miles from each other will mutually attract each other four times as strongly as if they were four miles apart, and a fourth as strongly as if they were one mile apart. That is the principle.

Now, the sea on the far side of the earth is 8000 miles further away from the moon than the sea on its near side, and further off, too, than the general globe of the earth, and therefore it is attracted less strongly, and comparatively speaking is left behind. Or we may put it in this way: when the moon is in its zenith and causes a full tide,

it does so by drawing the sea on its own side of the earth towards it, but it draws not only the sea on its own side of the earth towards it; it draws also to a less extent the earth itself, while the sea on the other side, being farther away from the gravitative influence, is pulled to a less extent still, and so is left behind.

Theoretically speaking, spring tides should be at full moon and new moon, and full tide should be when the moon is at its zenith, but the tide seldom occurs in accordance with theory, chiefly because of the interference of the land. Only in the Pacific and Southern Ocean can the tide run along without interference; in all other parts of the world it is twisted and checked and diverted by land. But even where high tide is not coincident with the meridian ascent of the full and new moon—*i.e.*, does not always occur at twelve o'clock—it always occurs with regularity; and if we know the time of full spring tide we can time all subsequent tides. If the time of high water at any port on the day of full and new moon be noted, it will be found to occur always at the same hour; and this hour is called the *establishment of the port*. Since the tide, of course, flows progressively onward, the establishment of various ports in the line of flow is consecutive. Thus the tide flows up the Channel and reaches Plymouth a certain number of hours before it reaches the Isle of Wight, and reaches the Isle of Wight a certain number of hours before it reaches Dover. This interval between port and port depends on the establishment, and is, of course, constant. Thus high tide at Liverpool is about two and a half hours earlier than at London, and high tide at London Bridge is two hours later than at the Nore. It must be fully understood that the backward and forward movement of the tides is due simply to a rise and fall of the water level, and the extent of this rise and fall varies exceedingly. In the open sea the tidal wave rises only two or three feet, but in narrow channels and bays the rise and fall may be very great. In some parts of the Persian Gulf and the China Sea the tides reach a height of thirty-six feet. In the Cardiff docks the lowest neap tides rise twenty feet, and the highest spring tides over forty feet. In the Straits of Magellan, tides of nearly sixty-six feet high have been measured; while at the top of the Bay of Fundy, in Nova Scotia, the rise at spring tides is more than seventy feet. "Twice a day immense neutral shores, which are neither land nor sea, change into deep gulfs, and stranded ships rise and float with sails spread, whilst towns lost in the interior of the land find themselves on peninsulas invested by the sea." In the bay of St. Michael, on the western coast of Europe, there is a magnificent tidal flow which produces transformation scenes twice a day. "At low water, the immense sandy plain, above one hundred and fifty miles in extent, resembles a bed of ashes, but when the tide, swifter than a horse at full gallop, rises foaming over the scarce perceptible slope, a few hours are sufficient to transform the whole bay into a sheet of greyish water, penetrating far up the mouths of the rivers as far as the quays of Avranches and Pontorson. At the ebb, the waters retire with the same speed to nearly six and a quarter miles from the shore, and lay bare the great desert strand, which is intersected by the subterranean deltas of tributary



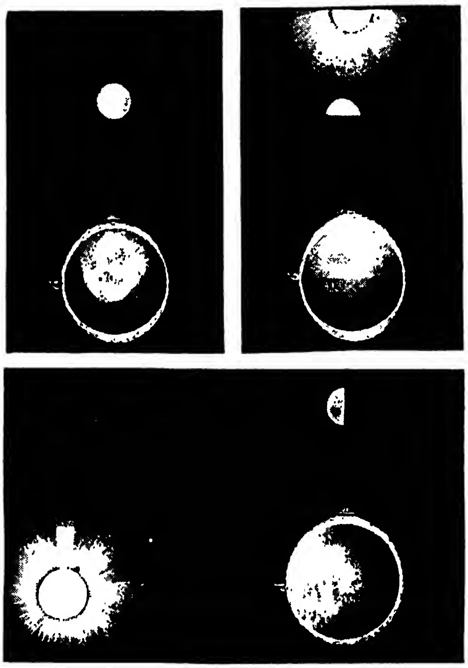
THE PROGRESS AND THE DIRECTION OF THE TIDES ROUND THE BRITISH COASTS

riverlets, forming here and there treacherous abysses of soft mud into which travellers are in danger of sinking."

In certain straits, very rapid and powerful currents or "races" are caused by the tides. In the strait, for instance, between Cape La Hogue and Alderney a current flows at a rate of nearly ten miles an hour. Between the islands of Jura and Scarba, on the western coast of Scotland, there is an even faster current.

When currents meet they sometimes alternately prevail, giving rise to a to-and-fro movement. The so-called Maelstrom, to the south of the Lofoten Islands, is made in this manner, but it has not the whirling whirlpool motion ascribed to it by legend; it is merely a swaying current with lateral eddies. Of similar nature are the currents in the Straits of Messina immortalised in the myth of Scylla and Charybdis.

In numerous cases when tides flow up rapid rivers or the estuaries of rapid rivers they cause a rapidly advancing wave which is known as a *bore*. Thus the Amazon, the Hooghly, the Seine, the Dordogne, the Elbe, the Weser, the Severn, and Trent all have well-marked bores. The bore in many cases produces a roaring noise which can be heard a mile away. The bore of the Amazon is called *pororoca*, because of its roar, and its wave is thirty to fifty feet high.



HOW THE TIDES ARE CAUSED

The two upper pictures show the spring tide when the moon is full and when it is new, the sun and moon pulling in opposite directions or together. The lower picture shows how the neap tides occur when the sun and moon pull at right angles to each other.

In inland and enclosed seas tidal motion is very slight. In Lake Michigan the tide is only three inches in height, and in the Mediterranean and Baltic it is also only a matter of inches.

It is interesting to note the importance of the tides to commerce. All the principal seaport towns—London, Hamburg, Havre, Bordeaux—have been built just as far inland as the tide will permit; and were the moon to cease to draw up the tides it would mean ruin to the shipping trade of these towns. Venice exists by permission of the sea.

It is quite obvious that the tides—the motion backwards and forwards and upwards and downwards of great volumes of water—imply great mechanical power; and no doubt some day the difficulties of utilising that power will be overcome.

There are other pulls on the sea besides the pull of the moon. Besides the fluctuating lunar tides, there are constant tides due to the pull of mountain masses. The sea surface is 300 feet nearer the centre of the earth at Ceylon than at the Indus Delta, where the sea water is attracted by the mighty mass of the Himalayas; and Professor Hull estimates that the gravitative attraction of the Andes is sufficient to raise sea level on the west coast of America 2000 feet higher than sea level at the Sandwich Islands. Even though the rocks of the sea bottom be denser than the rocks of the land, still that cannot quite counterbalance the mountains. And the sea level varies not only according to gravitative pull; it is also piled up by heavy rainfalls, and rivers, and currents, and it may be considerably depressed by rapid evaporation.

It may be noted that the general level of the surface of the sea is lowered to some extent by its compressibility. Water is a heavy substance, and the pressure in the depth of the sea is very great. For every mile in depth the pressure increases about one ton per square inch, so that at the bottom of the deepest sea the pressure per square inch must be more than four tons. This pressure compresses the water of the sea to some extent, but water is also perfectly elastic, and returns at once to its original volume when the pressure is reduced. If water were not compressible, the average level of the ocean would be about two hundred feet higher than at present. No doubt the elasticity of water comes into play during storms, and assists the wind to make waves.

WHERE A PLANT'S SEEDS ARE DEVELOPED

This highly magnified photograph of the ovary of a dandelion floret shows the numerous cells that are produced from division of the primary germ-cell, thus forming the seeds which perpetuate the hereditary characters of the species into the new generation which grows from them.

From a photograph by Mr. J. J. Ward

THE GERM-PLASM THEORY

How Far Life, Passed on from Generation to Generation, Belongs to the Race, or is Modified by the Individual

THE STUDY OF HEREDITY BY WEISMANN

Though Francis Galton was the first to cast doubt upon the generally accepted view that characters due to functional modifications of the body of the parent are transmitted to the offspring, yet it is to a German contemporary of Galton's, somewhat his junior, that we owe the evidence and the ideas upon which the modern study of heredity is based. This illustrious thinker, second now only to our own Alfred Russel Wallace as a surviving pioneer of organic evolution, is August Weismann, of Freiburg, now passing the eighth decade of his life amid the homage of students of life everywhere. His great book, dedicated to the memory of Charles Darwin, was published in 1892, when the author was approaching his fiftieth year - which was Darwin's age when the "Origin of Species" was published—and it was the fruit of ten years' continuous study of our problem, added to the biological work of many years before. Like Darwin's book, therefore, it is no hasty or immature production, but represents the long and exhaustively considered verdict of a master, after full reflection and repeated resort to Nature in confirmation of his views.

In this respect Weismann's theory markedly contrasts with Darwin's own theory of heredity, called "pangenesis," which was based on no evidence at all; and the younger thinker's theory is further contrasted because it is the exact opposite of Darwin's, which we have already dealt with in this section. Here, indeed, are Weismann's own words, in the modest and dignified preface to his book, of which the title is "The Germ-Plasm: A Theory of Heredity." He says: "The 'pangenesis' of Darwin seemed to me to be far too independent of facts, and now I am of the opinion that the very hypothesis from which it derives its name is untenable. There is now scarcely any doubt that the entire conception of the production of the 'gemmules' by the body-cells, their separation from the latter, and their 'circulation,' is in reality wholly imaginary. In this regard I am still quite as much opposed to Darwin's views as formerly, for I believe that all parts of the body do not contribute to produce a germ from which the new individual arises, but that, on the contrary, the offspring owes its origin to a peculiar substance of extremely complicated structure, the 'germ-plasm.' This substance can never be formed anew; it can only grow, multiply, and be transmitted from one generation to another. My theory might therefore well be denominated 'blastogenesis' or origin from a germ-plasm, in contradistinction to Darwin's theory of 'pangenesis,' or origin from all parts of the *body*."

The theory of Darwin, that the germinal material is formed from all parts of the parental body, was a very useful and natural one in its time. But, as Weismann says, when Darwin put forward his suggestion, "it was not possible to found any theory of heredity on the only sound basis —that of a knowledge of the most minute cell-structure." It was Weismann's work with the microscope that led him to substitute the idea of a part of the parental body separate from the first, in the body but not of it, which he called the germ-plasm. First stated in 1883, this theory now comes to be considered by us three decades later. Meanwhile, the work of Mendel has been rediscovered, and his followers have supplemented and modified the views of Weismann by their own method of experimental breeding. But the method which studies the germinal material with the microscope remains and will always remain. We now have to summarise and

pass revised judgment upon the work which definitely reversed our ideas of the relation between the body and the germinal material; we must note the conclusions which follow from Weismann's theory of heredity; and we must carefully correct an all but universal misunderstanding of his theory, which he has himself been at pains to make inexcusable.

The microscope established once and for all the fact that the hereditary material consists of cells, and it soon began to be suspected that the nuclei of these germ-cells were their essential part. That we now hold to be established, though the most recent writer on the subject has suggested that perhaps the body of the germ-cells, the mere protoplasm outside the nucleus, may be also concerned in the transmission of characters. However that may be, the supreme place of the nuclei is unquestionable. Weismann early fixed upon the nuclei of the germ-cells, produced respectively by male and by female bodies, as constituting essentially what he called the "germ-plasm."

The Invention of the "Germ-Plasm" by Weismann as a Speculative Necessity

By the germ-plasm he meant a something of which he felt bound to assume the existence, when he looked at the facts of heredity, "a special organised and living *hereditary substance*, which in all multicellular organisms, unlike the substance composing the perishable body of the individual, is transmitted from generation to generation. This is the theory of the continuity of the germ-plasm." We are, and shall be, at pains to quote exactly from an author who is much oftener named than read.

This germ-plasm, we observe, began as a speculative necessity. There must be such a thing, Weismann argued, if we did not grant the theory of Darwin that the body improvised its germinal material, so to say, from and for itself. That theory could not be held; and the only alternative was this of a special hereditary substance, the germ-plasm, essentially continuous from generation to generation, not subject to natural death, like the bodies which housed and transmitted it, and therefore potentially immortal. And, as we have seen, the next step was to give this almost mystical entity, already named, a local habitation in the nuclei of those living cells which the microscope identified as the germinal material that leaves parental bodies and becomes the offspring.

So long as we deal with species of animals or plants which have only one sex, or with cases where, though the species exhibits both sexes, the females can reproduce alone, no difficulty arises. But wherever we have bi-sexual reproduction, with the union of two germ-plasms, there must be, Weismann argued, a "reduction of the germ-plasm," in each case, so that the two germ-plasms, each essentially halved before union, may unite to form a whole, for the formation of the new individual. Otherwise, of course, in each generation formed by sexual reproduction the quantity of the germ-plasm would be doubled.

The Theory of Reduction of the Germ-Plasm to Half its Germinal Material

This theory of the reduction of the germ-plasm was almost as daring as those from which it sprang, the theory of any such thing as the germ-plasm at all, and the theory of its continuity and potential immortality from generation to generation. Very few theorists, however, have thought so well and wisely as to be justified by subsequently ascertained facts as Weismann has been. He asserted a "reduction of the germ-plasm," and located the germ-plasm in the nuclei of the germ-cells. Yet when we look at a germ-cell, male or female, of any species of animal or plant, it seems to be quite entire, not at all one-sided, or like the split half of a cell. It was a very daring notion that each germ-cell, though visibly complete, yet only contained half of the germinal material proper to the species it belonged to, and that somehow, in the formation of that germ-cell, the other half of the germinal material had been lost.

The Justification of Weismann's Theories by Subsequently Ascertained Facts

Yet, as we already know, exact experiment and microscopic observation justified this remarkable thinker. When the nuclei of germ-cells were examined, and especially when the processes leading up to the formation of the ripe or mature or final germ-cells were observed, a "reducing division," as Weismann called it, was demonstrated, in which one half of the nuclear material was removed or lost, so that each ripe germ-cell, though entire and complete as a cell, did yet afford only one-half of its essential contents.

A further idea forces itself upon us when, with this idea of the germ-plasm in our minds, we contemplate the various species of animals and plants. According to

Weismann—and we are now all agreed as to his rightness—the differences between a sheep and a dog, for instance, must be due to the fact that the body of the sheep is developed from sheep germ-plasm, and the body of a dog from dog-germ plasm. It follows that there must be as many different kinds of germ-plasm as there are species of many-celled animals and plants, and of course we ask ourselves in what these differences consist. This is a question indeed, for ew know that we may look through the microscope at the germ plasm of man, the oak, the ox, the mouse, the lily, and find very little difference between them; a cell is a cell, a nucleus is a nucleus, and there is little more to say. Indeed, many people, including some who should know better, have argued most improperly, as if the apparent similarity between the germinal material which will develop such different results were real, and as if it were much of a toss-up, so to say, whether a man or a monkey should develop from the germinal material in any particular case. But nothing whatever could be further from the truth. The similarity between the germinal material of such various species simply proves how far our microscopes are from seeing into the depths.

The Humility of Weismann an Example to Lesser Thinkers

It is a great pity that the popular writers on this subject, especially those who care for it not on its own account but as an argument in favour of materialism, have not derived from Weismann not only some of his mere knowledge, but also some of the wisdom which caused this great and humble thinker to conclude his masterpiece with the words : " We are thus reminded afresh that we have to deal not only with the infinitely great, but also with the infinitely small ; the idea of size is a purely relative one, and on either hand extends infinity."

Thus clear-seeing Weismann made the only just inference from the microscopic similarity of different germ-plasms, which we have just described. He saw that there must be what he called an " architecture of the germ-plasm," ultra-microscopic in dimensions, but none the less real and characteristic ; and that this architecture is special and unique for the germ-plasms of each and every species. The germ-cells that would have become the beginnings of monkeys, mice, or men may be substantially indistinguishable by any microscope, but if we could see closely enough into the details of their architecture, we should find them just as characteristic and just as different as are the developed bodies of a monkey, a mouse, and a man.

Of course, no one's mind can stop there. Once we realise that, in the tiny cell under our microscope, there is such a structure that when two such cells, essentially similar, unite they will produce a horse, or an oak, or a man, we are bound to ask ourselves what the details of its so amazing architecture can be. Perhaps the reader appreciates the attractiveness and the unthinkable difficulty of the problem. At any rate, we have all been arguing about it ever since Weismann's propositions were first laid down, and we shall argue about it for ages to come, beyond a doubt.

The Over-Elaboration of Weismann's Idea of Architecture in the Cell

Just in the very latest times we have begun to think of the problem in terms of chemistry, as will be seen, but until then it presented itself as wholly one of physical structure, or, to use Weismann's own term, architecture. Weismann himself has constructed a most elaborate and ingenious description of what, as he supposes, must be the architecture of a germ-cell. Innumerable writers have criticised his views and have put forward views of their own. Weismann has gone on elaborating his scheme and multiplying his names of structures supposed to exist in the germ-cell, which no one has ever seen, or ever can see, even if they exist ; and thus he has laid himself open to a great deal of ridicule and destructive criticism. He has overloaded his fundamental ideas with so much further and dubious material that the whole structure has long been top-heavy. Here we shall pay very little attention to this part of Weismann's work, which is not in the least degree essential to Weismannism, properly so-called, and which is merely the centre of an interminable and futile controversy, where the game seems to be to find out who shall coin the largest number of the longest new words in the shortest time.

The Waning of the Idea of Architecture in the Cell under the Discovery of Chemical Action

But our chief reason for avoiding any detailed reference to the views of Weismann and the other microscopists and theorists regarding the architecture of the germ-plasm is that the results of modern Mendelism are hinting at a chemistry of the germ-plasm which shall be something deeper even than its architecture. We are beginning to see how the development of this or that feature in the body of the new individual may depend not upon the existence, in the germ-plasm,

of some special tiny structure from which it was formed as the creature grew, but perhaps upon the presence or absence, in that germ-plasm, of a particular chemical ferment, the presence of which would initiate a certain series of developments, ending in some particular characteristic of the individual, whereas in the absence of this chemical initiative none of those changes would occur, and the particular final result in question would also be absent. The reader will observe the radical difference between such an idea and the idea that, for each characteristic organ or feature of the body, there must have been a corresponding group of units, having a particular arrangement, or "architecture," in the germ. That older view led to endless difficulties; and Weismann's statement of it, and those of his critics, were always in need of further elaboration and piling up of complexities, in the hopeless attempt to imagine some architecture of the germ-plasm which should somehow comprise, in that little space and in that simple guise, a sort of counterfeit presentment of the adult body in all its myriad parts. Here bio-chemistry, or the chemistry of life, is beginning to come to our aid, and is making most of the top-hamper of Weismannism obsolete. We shall confine ourselves here to its great principles, which have undoubtedly triumphed.

Weismann's Location of the Germ-Plasm in the Nuclear Chromatin of the Germ-Cell

We have said that the germ-plasm has been given a local habitation in the nuclei of the germ-cells from which all the higher animals and plants are developed. We must try to locate it more narrowly still. The centrosome, which initiates nuclear division, is no part of the germ-plasm. The germ-plasm is equally present in the nuclei of germ-cells derived from male and female organisms, though only one of these may possess a centrosome. But we have already seen that the nuclear substance of a germ-cell, like that of any cell, consists of two distinct and sharply contrasted parts—one which readily takes the colour of certain dyes, being therefore called the chromatin, while the rest of the nucleus does not stain with those dyes, and is therefore called the achromatin. When the nucleus undergoes the changes associated with division, we learn that the chromatin is the all-important substance. It is the chromatin that breaks up into chromosomes, which are split and distributed between the daughter-cells. On these grounds Weismann has located his germ-plasm in the chromatin of the nucleus, or, in his own words, "the chromatin must be the hereditary substance."

We have already seen how far the microscope will take us in the study of the germ-plasm, assuming that the nuclear chromatin in a germ-cell is the germ-plasm. The microscope shows that the chromatin breaks up into chromosomes, which split. It also enables us to detect, more or less distinctly, a row of smaller units within each chromosome, in some cases. But there the microscope leaves us. It becomes necessary to have recourse to the microscope of the mind in order to form some idea of what *must* be the ultimate structure of the germ-plasm—which has to account for all the characteristics of the developed body of a tree, a whale, or a man.

What Imaginative Inference says when the Microscope Fails to Carry us Farther

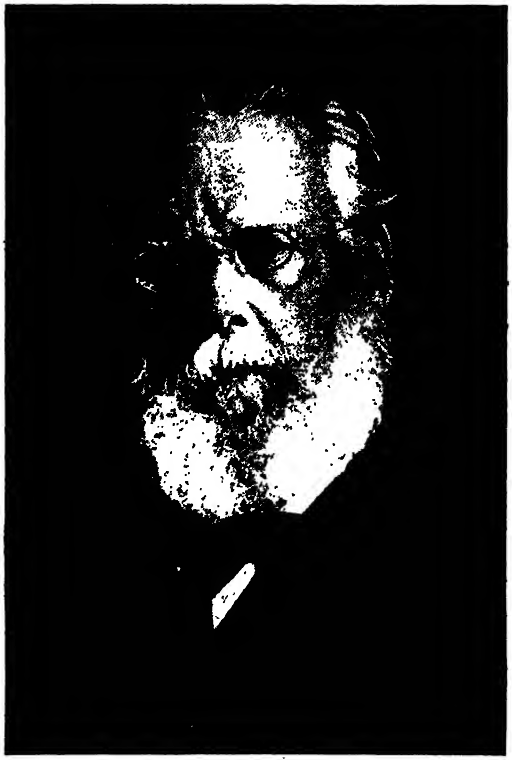
Here we shall only follow Weismann in mere outline, and cautiously, remembering how difficult and speculative our inquiry must become from the moment at which the microscope fails us. But Herbert Spencer has already prepared us, in some degree. He argued that the substance of a living body must be made up not merely of cells, nor merely of chemical molecules, themselves lifeless, composing those cells, but also of units, smaller than cells, but larger than molecules, and individually alive, which he called physiological units. Undoubtedly there must be such things; and Weismann, like all students of this subject since Herbert Spencer, has recognised the necessity of their existence, and has named them afresh. In Weismann's system these smallest units of living substance, called "physiological units" by the first man to recognise that they must exist, are called *biophors*, or "bearers of life."

The Infinite Complexity of the Most Minute Physiological Units

People are sometimes guilty of speaking of a "molecule of protoplasm," but this only means that they can have no idea of the complexity of protoplasm or living matter. The simplest protoplasm must consist of groups of molecules, each group containing many different kinds of chemical molecules. Each such vital or physiological unit is itself alive, and a biophor, or bearer of life. It is the smallest imaginable portion of living substance, and we must suppose it to be capable of nutrition and respiration, excretion, growth and multiplication. We say we must suppose it to be so capable, but we are the sorriest fools if we suppose that

we understand how it can be so capable. Only in terms of something which is purposive Mind can we now be satisfied.

But next we have to conceive of these ultimate vital units or biophors, each consisting of a group of various chemical molecules, as being themselves grouped so as to form larger units within the germ-plasm or chromatic substance of the nucleus of a germ-cell. These larger units, each composed of various but perfectly definite numbers and combinations of biophors, are called determinants by Weismann; and this name has become famous in biology. There is no doubt that something of the nature of Weismann's determinants must exist in the germ-plasm, and he gives them this name because each determinant must be regarded as determining the development of the various features of the future body. Thus, for instance, Weismann conceives that there must be a special determinant or group of biophors in the germ-plasm of any of the higher animals which will lead to the development, in its body, of the red blood corpuscles. These are all similar, but different from everything else in the body; and therefore it is argued that they must be represented in the germ-plasm by a determinant, which determines their formation. Further than this point we shall not follow Weismann in this particular direction; but he has a further building up of determinants into "ids" and "idants," and so forth, which have been immensely discussed, but are losing their interest in these Mendelian days. Still more complicated must the speculations become when we try to account for new characteristics or true variations, in terms of what happens among these biophors and determinants and so on; but while these speculations may here be wholly ignored one fundamental truth of the first importance, which we owe above all to Weismann, must be stated. It is, in his own words, that: "Since all parts of the organism are determined from the germ onwards, permanent variations in these parts can only originate from variations in the germ." In other words, true variation is something that happens in germ-cells, and there alone.



AUGUST WEISMANN
From a photograph by C. Ruf, Friedburg-im-Briesgau, by courtesy of the Linnean Society.

Nowadays we hear much less than formerly of Weismann's "determinants," but we yearly hear more about "factors" in the germ-cells, which are responsible for the characters of the developed individual. These "factors," which the Mendelians are bound to assume in the germ-cells, and the behaviour of which they are elucidating, correspond in all essentials to Weismann's idea; but again we must note that, while Weismann thought of his "determinants" in the language of architecture, modern genetics inclines to think of its "factors" more in terms of chemistry—such as the presence or absence of a particular kind of ferment in the germ-cell.

True variation, we said, is something that happens in germ-cells; and this leads us on to the question of the origin of germ-cells. In a few cases a true "continuity of germ cells" from one generation to the next can be observed; for when the fertilised "zygote" divides, it begins by setting on one side, so to speak, the germ-cells for the next generation, and then proceeds to form the body which will house them. But as a rule this cannot be observed. Even so, we have evidence to show that, at a very early stage, part of the developing individual is set aside for the formation of the germ-cells, while the rest goes on to form the individual body. That is all we can assert, in terms of the visible, but it is sufficient, if it be

understood to justify us in assuming that some special germinal material, the germ-plasm, has been handed on continuously from one generation to the next, and has not been made by the body of the individual.

So much we must grant to Weismann, but unfortunately too many students of biology have rested content with these striking phrases about the continuity and immortality of the germ-plasm, and have forgotten the very certain and long-known fact that the process of formation of the actual germ-cells goes on in the body of the individual, though not exactly *by* the body of the individual, of either sex, throughout the whole of its reproductive period.

The Relation Between a Continuous Germ-Plasm and Individual Development

To forget this is to erect the doctrine of Weismann into a worse than useless fetish: and we must beware. Needless to say, Weismann never made such a mistake himself. On the contrary, he it is who described the phenomenon of "reduction," whereby the number of chromosomes is halved when the final "ripe" germ-cell is formed, ready for mating. This ripening or maturation of the germ-cells, as it used to be called, occurs, of course, in the body of the individual, and involves active processes of nutrition which are dependent upon the blood of the individual in whom they occur. These ripenings and maturations, which present strange and characteristic features in both sexes, are now fairly well understood; and we shall see that unparalleled importance must really attach to them in relation to the origin of true or germinal variations. The modern name for this process, as it occurs in either sex, is gametogenesis, as we have seen, its results being the gametes or marrying cells, which are the final, ripe germ-cells, capable of mating to form the new individual, or zygote.

Necessary Precautions against an Unreserved Acceptance of Weismann's Theories

Let us, then, by all means accept the essential teaching of Weismann as to the continuous germ-plasm, not made from he body of the individual, but the maker of the body, which then houses it, and passes it on. But let us also realise that this is a half-mystical doctrine, which must not be held in any such form as to deny the known facts of observation. The chief of those known facts is that the germ-plasm takes its active embodiment in germ-cells—obviously, if it is not in them it is nowhere—and that these germ-cells are not simply a collection of finished products, which the body is provided with from the first, and then merely houses, but are cells that are constantly being made, in the body, from preceding cells found in the testis or ovary of the body in question. The vital importance of this fact of gametogenesis is two-fold.

First, we have to conceive of the germ-plasm as intensely alive, active, changeable, dynamic, *not* as a passive and constant thing, immutable and immortal, which is simply handed on from generation to generation unchanged. It must be intensely alive, which means intensely changeable, for, in point of fact, throughout the whole reproductive period of the individual, this germ-plasm, which we have located in the chromatin of the nuclei of the germ-cells, and of the precursors of the germ-cells, is producing those germ-cells, each unique and distinctive. The differences between brothers and sisters of the same parents are ultimately determined by the determinants in the germ-cells whence their bodies were formed; and just as brothers and sisters differ, so must the various germ-cells, produced even from the germ-plasm of one particular person, differ also and equally.

The Confirmation of Weismann's Theory by the Experiments of Mendelism

The formation of ripe germ-cells, or gametogenesis, as we now call it, is therefore the process in and by which the endless variations of living things are created; and plainly we must study gametogenesis with unheard of zeal in consequence, for upon its variations all organic evolution depends.

After a perion of doubt, due to the misunderstandings of "biometricians," who confounded the mere effects of nurture with true variations, we have come back to the view set forth first by Weismann: that bi-sexual reproduction is a cause of variations. We see that the process of gametogenesis, and reduction of the chromosomes, so that each gamete is in a sense only half a cell, though it appears to be structurally complete, must lead to the production of variations, because of the mixture of two germ-plasms, and the creation of a new and unique germ-plasm in consequence, whenever a new zygote is formed. This theory of Weismann, by which he explains the utility of bi-sexual reproduction at all, is now absolutely confirmed, of course, by the facts of Mendelism, which show the importance of each particular mating of two gametes, and the

consequent production of variations, which may sometimes be very startling and sensational.

But the recognition of this process of gametogenesis, steadily occurring in the body of the mature individual, is of vital importance for a second reason, as we have said; and this is that we now learn how greatly the "germ-plasm," with all its "immortality," is dependent upon the body which houses it. Thus, if that body is equipped with blood in which lead, alcohol, arsenic, certain disease toxins, or other racial poisons, as the Eugenists call them, are contained, the process of gametogenesis will be prejudiced accordingly, and the results may be of the gravest. On the other hand, the body of the individual in which gametogenesis is occurring may be providing the germ-plasm with perfectly healthy and abundant blood, so that gametogenesis will occur favourably. But, unfortunately, these quite obvious truths, fully appreciated by Weismann himself, are apt to be ignored by those who have not read, but who have accepted, without examination, the doctrine of the continuity and immortality of the germ-plasm, and of the non-transmission of acquired characters.

The Effect of Nutrition, Good and Bad, Upon the Next Generation

They thus assume that the germ-plasm is not merely immortal in Weismann's profound sense, but immortal and inviolable in the sense that nothing which happens to the body can affect the germ-plasm. This is palpably foolish, for we know that if and when the body dies, the germ-plasm it contains must die also. And similarly, as Galton and Weismann have most carefully stated—apparently to little purpose—the nutrition of the body in general may affect the germ-plasm and the process of gametogenesis for good or for evil, as has now been exhaustively proved, both in animals and plants, in the case of many kinds of disordered or abnormal nutrition.

This is a fact of high importance for eugenics, no doubt, but it is of at least equal importance for the science of life, showing that the variations which arise in the process of germ-cell-formation, or gametogenesis, and which are the essential condition of all organic evolution, may themselves be conditioned by the nutrition of the individual body in which these processes are occurring. We thus return to reason and common sense, and the doctrine which Lamarck taught a century ago. If the reader cannot distinguish between the assertion that, say, development of the parental biceps will modify the germ-plasm so that the child will have a bigger biceps than otherwise, and the proposition that, though this does not happen, yet the nutrition of the parental body affects the germ-plasm which it houses—well, there is no help for it. He has the consolation of being in distinguished company, but Galton and Weismann themselves are not of the number.

The Variation of Germ-Plasms in Consequence of External Influence

When Galton denied the so-called "transmission of acquired characters," he carefully excluded the infection of germ-plasm by microbes, and the influence of disordered nutrition. Wiesmann has carefully done the same, in the twelfth chapter of his great work. He points out that what occurs to the germ-plasm in many cases of parental alcoholism is not, strictly speaking, a problem in pure heredity, but is simply "an affection of the germ by means of an external influence," and we see what he means. But in one respect we must modify his conclusion, now, twenty years later. He argues that such affections of the germ by an external influence, such as alcohol, quinine, or what not, will produce degeneration, but he denies that any such chemical treatment, as we may call it, of the germ-plasm can cause the development of new and positive features. There, however, modern experiment is against him, for the American botanists have definitely produced new forms by just such processes. Weismann has himself subsequently admitted that in earlier days he "did not attach sufficient importance to the variation of the germ-plasm in consequence of influences acting directly."

Disciples Who are More Favourable to a Master's Ideas than the Master

With that very important admission, still ignored by the too faithful Weismannians, who are "plus royalistes que le roi," we may leave this great pioneer, whose leading ideas are now part of the accepted achievement of biology, and who has lived on into the new epoch when his ideas of the nature and origin of germ-cells are being immensely extended, as well as confirmed, by the application of the discovery which Mendel made, some years before Weismann began to write at all. With this chapter, then, an era in biology closes; and we proceed to the new-old work of the solitary pioneer of Brünn, which dominates all our inquiries to-day.

THE DEVELOPMENT OF A GRAIN OF WHEAT

This series of photographs illustrates the progressive stages in the germination of a grain of wheat. 1, shows the seed as placed in moist soil on a certain day at noon; in 2, photographed some six hours later, can be seen at the base of the seed a tiny excrescence, which is the embryo, receiving moisture down the channel shown in 3, gathered from the fine hairs at the other end; 4, 5, and 6 show the stages reached at noon on the second, third, and fifth days respectively; and in 7, photographed on the sixth day, the radicle has grown considerably. On the seventh day, shown in 8, the plumule can be seen growing upwards, and two roots have shot out on either side of the radicle, all three being covered with moisture-collecting hairs. On the twelfth day (9) the development of plumule and roots is considerable, but the grain which has fed them is lessened in bulk.

A PLANT'S FIRST GROWTH

Conditions of the Germination of Seeds, and Their Purposeful Stroke Downward and Upward

EASY EXPERIMENTS WITH THE BEAN

We have now to take up some of the further problems of growth and the function of reproduction; and at this stage we shall confine ourselves to the study of these processes as they are connected with seeds. At a later stage, when we study the organs of reproduction in flowers, for example, we shall have to consider some further points.

The most common way to raise a crop of almost any plant is by the sowing of the seeds produced by a former generation of the same species. True, as we have seen, there are other ways of producing new plants, but the sowing of seeds is the process that rises in the mind as the initial stage of the production of a new crop. It is therefore essential that we should understand something of the nature of a seed, and of its marvellous capabilities. To the ordinary mind these are wrapped in considerable mystery, all the more obscure, perhaps, from the fact that the many different processes in connection with seeds are hidden from our observation, inasmuch as they occur under the ground. Some of them, too, are of such an extremely delicate nature, and on such a small scale, that it is necessary to call in the aid of the microscope, or at least a magnifying-glass, in order to observe them.

Still, there are some seeds sufficiently large and sufficiently common to enable them to demonstrate all the important processes quite easily. Anyone who chooses can study for himself the structure of a seed, and with his own eyes watch its development from the very earliest stages, until the plant itself is formed.

No better example for this purpose could be selected than that of the common bean, for it may be taken as a type to indicate the general structure of a seed. The wheat-seed also may very well be examined; and the illustrations in this chapter indicate clearly the different stages of development, and the structures concerned, which we are now about to describe.

If the pod of a leguminous plant, such as the bean, be opened when the seed is nearly ripe, it is found that each of the seeds is attached within by means of a short stalk. This stalk, or funicle, is really the means of communication between the maternal structures and those of the seed itself, and it is through it that the nourishment from the parent is transmitted for the development of the young seed. By and by the stalk dries up, and so ultimately allows the seeds to detach themselves from the parental connection. In order to ascertain exactly what such a seed is made of, it should not be allowed to become shrivelled up, but rather should it be soaked in water for a few hours, by which means its separate parts can be more readily distinguished.

The outer covering of such a seed is smooth, of a yellowish colour, and is characterised by a black mark at one end, which is known as the eye, or *hilum*. This represents the point at which the seed was attached to the funicle within the pod during its process of ripening. Close beside one end of the eye of the bean there can be seen, with the aid of a magnifying-glass, a very small aperture.

Its presence can be demonstrated in a soaked bean by gently squeezing the whole seed, when a little water will bubble out at this spot. Obviously the aperture, therefore, forms a means of communication with the interior, and apparently the only communication. There is nothing else on the outside which is noticeable.

The outer part of the seed can be very easily removed by simply cutting round the edge and stripping off the outer portion. When this has been done we see that we

have removed a sort of membrane, of tough consistence, and not quite transparent. This is the seed-coat, or *testa*. Within it the true seed lies, seen to be oval and somewhat flattened, and separable into two distinct halves, or *cotyledons*, which are united together by a little projecting portion known as the *radicle*. One end of this radicle is inserted into a hole in the seed-coat, which corresponds in position to the small aperture we have already mentioned. The other end lies between the two halves, or *cotyledons*, as is most distinctly seen if one of these halves be removed, when the bent radicle remains attached in position to the other one. Closer examination fails to reveal any other distinct parts of the seed, which in this undeveloped stage is therefore seen to consist of testa, or seed-coat, radicle, and the two cotyledons.

This is a simple enough structure, but it is, nevertheless, sufficient to contain within it all the possibilities for the growth of a complete bean plant; and the function of the various parts only becomes obvious when this seed, or bean, is either placed in the ground and allowed to grow, or else put under such other conditions of temperature and moisture as will stimulate it to growth similar to that which would take place if it were in the ground.

How the Seed Begins to Send Out the Root and Stem

Let us suppose that the seed is placed in such conditions, and that we can watch what happens. The first thing to which our attention would be drawn is that one end of the bent radicle grows longer, and very soon forces a passage through the seed-coat. The spot where it emerges through the coat is very close to the minute aperture, or *micropyle*, already mentioned, but not actually through it. Further elongation of this radicle soon causes the seed to assume the shape seen in 4 of the illustration on page 2003. A glance at this illustration suggests that the elongated radicle is becoming a root, and, indeed, that is the case, for this is the root of the new plant.

Part of it, however, remains between the two cotyledons; and this part, which is curved, also forces a passage out of the opening in the coat of the seed and grows upwards. Just as the lower portion suggested the growth of the root, so does this second outgrowth, as it straightens itself upwards, suggest a stem, and, indeed, this is a new stem from which the leaves are about to be developed. At this stage the appearance is that shown in 5, and we have now what we may term an embryo plant. The root and the stem together thus form an axis, passing through, as it were, the two cotyledons; and these two structures, root and stem, are known as the primary axis of the plant.

If we wish to know where the root begins and the stem ends, it is necessary to make a much closer examination of the structure within the axis itself. It is noticed that the upper part of the stem as it forces its way out from between the cotyledons is bent upon itself, and it remains in this curved attitude for some time. This forms a kind of protection for the developing tender leaves; and although this is not obvious in a seed that is being grown simply in water, it will be quite clear if a seed in the ground be examined at this stage.

A Simple Method by which Germination Can be Watched

Any who wish to observe for themselves the processes we have just described may readily do so by simply taking a few beans, soaking them in water for twelve hours, wrapping them up in some thick, damp flannel, and placing them between two plates, so that one plate covers up the beans in the flannel, and keeps in the heat—just as one would place a piece of toast to keep it warm. The beans can then be examined at intervals, and the flannel kept damp, when the appearance of the radicle and the curved plumule may be easily seen.

So much for the structure of the seed and the appearances that it assumes when growth takes place, but we must now turn our attention a little more closely to this starting of growth, or germination, for there are some important points in connection with it.

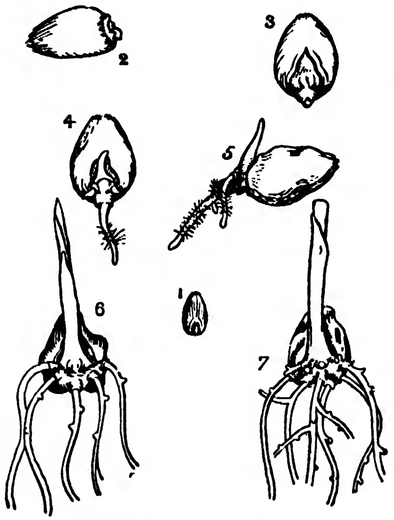
The Long Period of Time During which a Plant Embryo Can Live

As long as the seed is in the pod, it derives its nourishment from the parent plant from which it grows, but when it gets to the ripe stage it passes into a curious condition of inactivity. This stage may last for a very long time, during which no signs of life in the seed will be apparent at all. How long a seed may remain in this dormant, inactive condition is a much-disputed matter, and depends a good deal upon the kind of seed concerned, as well as on the environment in which it happens to be. It is a very curious stage, and is not entirely understood, but this much is certain: the embryo within a dormant seed will not live long unless the seed were thoroughly ripened first. A good deal, too, depends upon how the seed

is kept afterwards. Most of the seeds we use in our gardens, or for agricultural crops, fail to germinate if kept for more than ten years or so, and a good many will not survive for nearly that time. In fact, two or three years is the limit for some. On the other hand, seeds have been said to have retained their power of germinating for much longer periods.

This capacity for germinating, which constitutes, of course, the whole value of a seed, depends upon at least the following factors: the embryo in the seed must be alive; it must have supplied to it a certain amount of water; it must not be subjected to too great extremes of temperature; it is imperative that it shall have a supply of air or oxygen.

Curiously enough, it is quite impossible to tell by simply examining the outside appearance of a seed whether it is alive or dead. That is to say, external symptoms do not afford obvious evidence of the life of the embryo. The seed may be discoloured, apparently dried up, wrinkled, and otherwise disfigured to such an extent that it would appear hopeless to expect anything from it, and yet if it be placed under suitable conditions germination will follow. On the other hand, externally the seed may represent every appearance of being in a good condition, and yet when planted may fail to germinate, because the embryo within is dead. It is true, at the same time, that there are some seeds whose power of germination can be roughly, or partly, estimated by their colour, and particularly by their brightness, but no great reliance is placed upon such unreliable methods; and all seeds that are to be used should have their germinating power tested by putting samples of them under suitable conditions.



GERMINATION OF A SEED

1, Grain of wheat, natural size; 2, enlarged, showing protrusion of embryo on right; 3, the tip of the radicle beginning to appear; 4, a later stage, showing plumule growing and root hairs on radicle; 5, 6, 7, progressive stages, showing growth of plumule and roots and shrinking of the seed.

The most usual cause of failure for germination is that the embryo within the seed has perished. We are apt to forget that this is a living structure, capable of retaining its life for a wonderful length of time, but not capable of so maintaining it indefinitely. Thus, in the case of the wheat-seed, seeds which have been kept for more. than ten years are easily found to be quite dead, and even in three-year-old samples there will be far fewer seeds germinating than in a sample of wheat sown in the season following the crop. So the germinating capacity of the seed obviously deteriorates with its age. This is, of course, a very practical question, because it becomes of importance for the gardener and the farmer to have some kind of idea of the length of time he may keep seeds stored without impairing his chances of securing a reasonable crop.

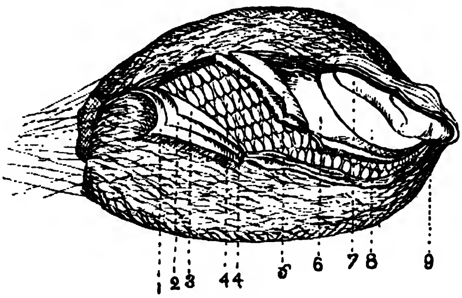
The following table is given by Professor John Percival to indicate the time beyond which it is inadvisable to use the seeds mentioned.

Wheat	2 years
Oats	2 years
Barley	1 to 2 years
Rye	1 to 2 years
Maize	1 to 2 years
Peas	4 to 5 years
Beans	4 to 5 years
Buckwheat	2 years
Turnip	3 to 4 years
Swede	3 to 4 years
Mustard	3 to 4 years
Mangold	3 years
Carrot	3 years
Cabbage	3 to 4 years
Kale	3 to 4 years
Kohlrabi	3 to 4 years
Clovers	2 to 3 years
Sainfoin	1 or 2 years
Lucerne	3 or 4 years
Most grasses	2 or 3 years.

The next condition necessary for germination is that there should be a sufficient quantity of moisture in the form of water. This can be seen at once experimentally by keeping seeds dry at different temperatures where they have an exposure to air, when it will be found that no growth occurs. On the other hand, if they be allowed access to moisture, not merely in the ground but even in a dish, the moisture is enabled to penetrate the seed-coat, and so reach the interior, passing especially through the minute aperture of the micropyle. This moisture very soon reaches the radicle, which, as we have seen, and as can be noticed in our illustrations, is the first part of the embryo to make its appearance. The immediate result of absorption of moisture is that the bean, or other seed, exhibits a considerable swelling, and its consistence is softer, these two changes preceding the appearance of the growing radicle.

But not only is it necessary that the

embryo should be alive and healthy, and that moisture have access to it in order that germination may take place—a certain amount of heat is also required. Gardeners and farmers observe this when they sow beans or other seeds in the ground during the winter months, when, instead of the radicle making its appearance in a few days as it does in spring and summer, the seed remains dormant until the temperature rises. There is great variation, however, in the actual temperature required to start the germination process. Some embryos make their earliest growth when the weather is only just above freezing-point, other species requiring much warmer surroundings. In every case there is a temperature at which that particular kind of seed germinates most readily. In the case of the bean it is about 28° C.



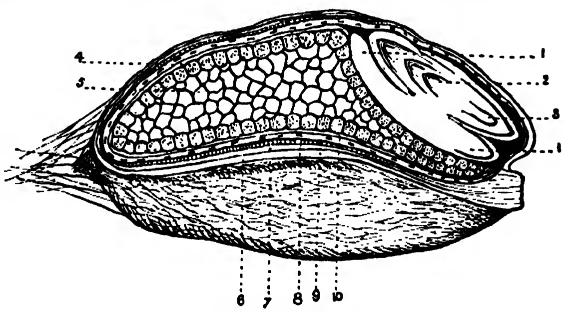
THE PARTS OF A GRAIN OF WHEAT
1, Epicarp; 2, mesocarp; 3, endocarp; 4, testa; 5, seed-coat; 6, endosperm; 7, plumule; 8, cotyledon or scutellum; 9, radicle; 7, 8, and 9 comprise the embryo.

A still further necessary condition of germination is a supply of air or oxygen, although it is not quite so easy to demonstrate the necessity for this. Still, it can be done by placing the seed in an atmosphere of hydrogen, or some other gas which displaces the oxygen of the air. Then it is found that, even though both moisture and adequate heat be supplied, still germination does not now take place.

These three necessary factors of moisture, oxygen, and warmth immediately suggest to us that we are dealing with an actual process of life itself; and when we make a further experiment and notice that the growth of the seed does actually absorb oxygen from the air, and give off carbon dioxide into the air, we are still more convinced of the fact, because this is precisely what happens in the respiration of ordinary living creatures. Another proof can be offered in a simple experiment. If a few beans be placed in a bottle containing ordinary air, and the neck of the bottle be corked up, a chemical test at the end of twenty-four hours will show that the air has been replaced by carbon dioxide gas, the oxygen obviously, therefore, having been utilised by the seeds.

The actual part played by water in the process of germination has been already partly discussed in earlier chapters, but the additional point may be mentioned here that it is clearly of the greatest assistance in so softening the tough seed-coat as to enable the embryo to start growth, and penetrate its covering.

The earlier stages of growth, such as those illustrated in our pictures, depend entirely upon the two cotyledons for their supply of nourishment. These cotyledons, at first thick and bulky, will be observed, as growth goes on, to become reduced in size, getting considerably thinner. As a matter of fact, their interior is a storehouse filled with food for the maintenance of the growing embryo; and this suggests to us another important function on the part of the moisture absorbed by the cotyledons—namely, that it dissolves the nutrient matters and enables them to be carried to the embryonic areas themselves, and especially to the radicle and the young stem, as they respectively appear. The earliest stages of germination cannot occur in such a seed as the bean without the presence of the cotyledons, as can be easily proved by cutting off the radicle and the stem of the embryo immediately they have made their appearance and pushed themselves through the seed-coat. It will then be found that development ceases, the supply of nourishment having been cut off.

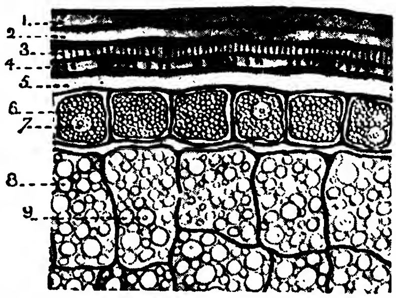


LONGITUDINAL SECTION OF A GRAIN OF WHEAT
1, Cotyledon or scutellum; 2, plumule; 3, radicle; 4, cells containing aleurone grains; 5, cells containing starch grains; 6, epicarp; 7, mesocarp; 8, endocarp; 9, testa; 10, seed-coat; 4 and 5 comprise the endosperm.

One of the most interesting points in connection with the process we are discussing is that of the movements that take place in the different parts of the young

growing plant. Such movements are quite clearly indicative that we are dealing with a living young thing, and one of a specific type. Thus, when the bean planted in the soil has reached a stage at which the radicle appears, this structure is observed to turn at once downwards into the soil, and continue to grow in that direction. This happens no matter in what attitude the bean was placed originally.

The stem, or plumule, exhibits movements equally definite, but exactly opposite in direction. From the very moment when it emerges from the seed-coat between the cotyledons, its tip, which is at the end of its curved portion (page 2003), begins to grow upwards in the opposite direction from the root; and, again, if the seed be uprooted and the position reversed, the experiment fails, the stem once more asserting its inherent living tendency to seek the surface of the soil. A very interesting experiment, that illustrates these marvellous movements extremely well, is to sow a number of beans in a shallow box, placing the seeds in a variety of different positions. If they be examined at the end of a week or so, the above facts will be made abundantly obvious.



A HIGHLY MAGNIFIED SECTION OF A GRAIN OF WHEAT
1, Epicarp; 2, mesocarp; 3, endocarp; 4, testa; 5, seed-coat; 6, aleurone grains in cells; 7, cell nucleus; 8, starch grains in cells; 9, cell nucleus.

We have taken the case of the bean as an example of the process to be noted in germination because the seed itself is a common one, and sufficiently large for its structures to be easily examined. It must not be thought, however, that the process differs in any essential particular in the bean from that which takes place in other seeds. It is, of course, perfectly true that seeds differ immensely in their appearance, size, colour, weight, texture, and so forth, but, nevertheless, they all have this in common: that every one contains within it a young embryo stored and protected between the seed-coats. These latter may be large or small, but the proportions only differ, not the structures.

There are few exceptions to this rule. The exact manner in which the embryo is disposed within the seed is not, however, the same in all kinds. Its size, its manner of appearance, and its rate of germination vary very considerably in different species.

In the case of the seeds of the white mustard plant, the two cotyledons do not remain inside the seed coat and below the soil as they do in the bean. Here these cotyledons escape together from the seed-coat and actually make their appearance above the surface of the soil, where they soon assume the appearance of ordinary green leaves. In fact, they are the first leaves of the mustard plant. A little later the stem appears between the two, and as it grows upwards develops from itself the secondary or rough leaves of the mustard plant.

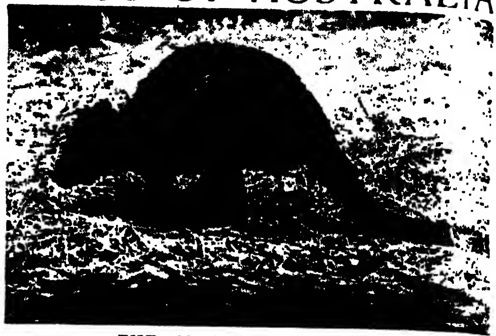
It may be well to mention in passing, since the term is in very common use, that all plants the embryos of which are characterised by possessing two cotyledons receive the name of *Dicotyledons*. This group is a very well known and numerous portion of our flowering flora.

Some seeds, however, do not depend entirely upon the cotyledons for their storage of food, even though they belong to the group of Dicotyledons just mentioned. For example, the seeds of the ash and the potato, both of this class, have a store of food quite distinct from the cotyledons. When such a separate store of food exists it is known as *endospermous*, and the seeds possessing this store are termed *endospermous*, or *albuminous*, in distinction to those of the bean and mustard type, which, having no separate storage of the kind, are termed *ex-endospermous*, or *exalbuminous*.

Finally, a grain of wheat is not exactly a seed, but a mass of nourishment that contains a seed. When germination occurs, the seed within the grain gradually comes to occupy the whole of the interior. The embryo takes up only a small part of the space, mainly utilised by a store of floury nourishment. When the embryo begins to grow it is seen to consist of a shield, or *scutellum*; attached to this is the plumule, this exhibiting a short stem with leaves of a sheath-like nature. Three rootlets usually appear. As the embryo grows, the *endosperm* diminishes, so it is obvious that this *endosperm* is the store of food upon which the young plant is dependent during its early growth. The shield has the function of transferring the food to the different parts of the growing plant.

THE CURIOUS KANGAROOS OF AUSTRALIA

BENNETT'S WALLABY AND ITS YOUNG



THE CERVINE KANGAROO

THE BLACK-TAILED WALLABY IN ITS NATIVE HAUNTS

GREAT GREY KANGAROOS

THE RED KANGAROO

The photographs on these pages are by Lewis Medland, W. P. Dando, C. Grant Lane, and others.

THE POUCHED MAMMALS

A Low Type of Small-Brained Animal Approaching the Reptile, and Developed Chiefly in Australia

THE FATE OF THE MONSTERS OF THE PAST

There may lurk a mystery in a shoe of patent leather, and that without reference to its wearer. Beneath the veneer of varnish there may be leather fashioned from the skin of a kangaroo, the hair from which may have gone to the making of a felt hat. Of all existing quadrupeds there is only one order lower than that to which the kangaroo belongs. That is the monotreme order, the order embracing the two egg-laying, warm-blooded mammals which suckle their young. Below that line come the birds and reptiles. The advance of the kangaroo in the scale of life is related to the fine coat that man converts into leather. Not the first kangaroo, but an ancestor, began its upward course, it is believed, by the reciprocal action between brain and hide. Between the interstices of the ancient mail there arose sensitive, unarmoured patches of skin, by which the brain could more readily receive communications than from the impervious armour covering the rest of the body. The brain developed under stimulation; the area of sensitive skin became more extended. The skin, instead of a horny covering, became a sort of instrument of touch, recording in the brain every contact with a foreign body. There resulted a swifter and more accurate placing of the limbs to meet swift-changing environment; and as the limbs became more readily controlled they developed amplitude, lifting the beast above the physical level of the reptile, as the growing brain lifted its owner mentally beyond the plane of the same order. So, beneath the varnish of the patent leather shoe may lurk the perfected record of one of the elements in the rise of the mammal above the cold-blooded egg-layer.

In order to avoid the use of technical terms in our heading, we have the line "pouched mammals." It must not be left at that. We have here to deal with the marsupials. Now, as we all know, the term "marsupial" is derived from the Latin "marsupium," meaning a pouch. A man handling a certain species of bat, *Chiromeles torquata*, may exclaim: "Here, then, is a marsupial!" For this bat has a pouch in which it carries its newly born offspring. But that is not a marsupial. Another man, finding the majority of opossums lacking the external pouch, will receive with incredulity the suggestion that opossums are marsupials. The fact is, the term "marsupial" is not in itself indicative of all the characteristics upon which the naturalist relies for the classification of the order. Apart from certain important peculiarities as to teeth and skull, and the contemptible character of the brain, there is a feature of the marsupial even more striking than the pouch from which the whole order derives its name, and that is the remarkable immaturity of the young at birth. The young of the largest kangaroo, an animal exceeding a man in height and bulk, is at birth a tiny, almost shapeless mass of flesh, only about an inch in length, hairless, and covered with so thin a skin that the blood-vessels are clearly distinguishable through it. The future king of leapers is so fragile and delicate that it can scarcely be handled without injury, so helpless that it cannot even suck, but, placed within the marsupial pouch and attached by its mouth to the teat of its dam, is fed by the injection of milk down its throat by means of muscles controlled by the parent. The mere act of swallowing has to be safeguarded by a special provision, the throat of this extruded embryo being, at this stage of existence, fashioned after the plan of the crocodilian or cetacean throat, in which swallow and air passage are kept apart to prevent choking. Here, then, are evidences as to the order to which the animal belongs. But correlated with these

is a pre-natal condition of an exceptional character.

All marsupials are non-placental; there is no connection between the developing embryo and the parent body, such as is found in the case of all the higher mammals. As the egg of a bird contains all the nourishment the chick will need until it bursts its shell and may be fed by its parents, so the fertile ovum of the marsupial requires only the warmth of the parent body. The period of pre-natal development extends to only thirty-eight or forty days, and then the embryo animal is born, more helpless than the most feeble of birds. The latter have at least the power to raise their heads and open their beaks to be fed, but that is a condition far in advance of the powers of the almost motionless little fragment of life which the marsupial mother pops into her pouch to nurse and nourish until form and strength and knowledge render the young kangaroo, or whatever it be, able to emerge competent and confident. One of the monotremes, the duck-bill, broods her eggs in a nest built at the end of a subterranean tunnel; the other, the echidna, or spiny ant-eater, places the eggs in her marsupial pouch and hatches them there. The kangaroo or its congener may be said merely to hatch the ovum within its body and produce the immediate result, more immature than the newly hatched bird, to rear it in a nest forming part and parcel of the parent animal itself.


THE VULPINE PHALANGER OR OPOSSUM

Authorities differ as to whether the marsupial is excessively primitive or merely degenerate. Formerly it was held to be the fact that the marsupalian was the ancestral type of mammals; it was a widespread order, and, in Mesozoic or Secondary times, had a pretty well world-wide range. Today the only marsupials existing in a state of freedom are restricted, the true opossums and the selvas to the American continent, the others to the Australian region. It seemed, then, judging by the data available, practically certain that all mammals had been developed from this or from an ancestral stock. The theory is not wholly abandoned. But later investigations have revealed suggestions, in the bandicoot, of a functional placental connection between the embryo and the parent. Is this a vestige or a rudiment? Is it a relic or a beginning? Are we to regard the circumstance as evidence that the non-placentals of today are the degenerate descendants of placental animals, or are we to think that the bandicoots are only at the outset of a placental development? Are we witnessing the end of a cycle or the beginning of one? None among us is qualified to return a positive answer. The clue to the puzzle lies still hidden in the rocks.

The fact as to which we are certain is that the marsupials, shut up for ages incalculable in terms of years, have attained their greatest development in Australasia. By what route they reached their vast asylum, by what land bridge they travelled thither from another continent, there is not yet clear knowledge. But we do know that at an early stage in mammalian development the great island continent of Australia received a group of mammals which has no living counterpart in the world to-day, and that, sheltered from competition with the rest of the animal world, they waxed mighty in bulk and numerous in species. With the exception of certain rodents and bats, they form the entire indigenous fauna of Australia. To that must be added a reservation. There is the mysterious dingo dog, which, as we have seen in a previous chapter, has been found in fossil form, but in proximity to other remains that do not exclude the possibility of its having been long ago introduced into the island continent by man's agency.

In certain of the islands adjoining Australia placental animals are found with marsupials. We must not jump to the conclusion, however, that the two types have developed side by side. The placentals are the descendants of other placentals that

reached these islands long after the way into Australia proper had sunk beneath the sea. With a world to themselves, the marsupials in Australia branched out in many directions. While the majority remained herbivorous, carnivorous animals developed among them. The hideous thylacine, or pouched wolf, now surviving only in Tasmania, had its kin on the Australian mainland, where it attained huge size and power, though it may not have been entirely carnivorous. The Tasmanian devil, too, was represented there. There were bigger kangaroos than any now to be found; while the diprotodon, a gigantic predecessor of the modern marsupial, attained the dimensions of a rhinoceros. Today no native carnivorous animal survives on the Australian mainland bigger than a small cat.

THE KANGAROO POUCHED RAT

This disappearance of the giants of the Australian fauna is a puzzling problem, ranking with that presented by the complete annihilation of the gigantic animals with which South America once teemed. Why should the mighty animals of insulated Australia have perished? So long as the herbivorous animals remained, there was abundant food for the carnivores; and the food that sufficed to maintain vast hordes of other marsupials must have sufficed for the diprotodon and its allies. There is a gleam of light in a theory enunciated by Professor A. Dendy at the British Association in 1911. Recalling that many groups of animals in the course of their evolution have shown a marked tendency to enormous increase in size, and that that tendency has been accompanied by the development of grotesque and apparently useless excrescences, he urges that a race of animals may acquire a momentum of a kind that might lead it to destruction. Normally, there would be a brake applied, as it were, to the growth of organs and organisms, and, if that brake were removed, the results might ultimately be fatal. It is generally acknowledged by physiologists that the growth of different parts of the animal body is controlled by internal secretions, the products of various glands; and there is reason to believe, Professor Dendy holds, that, in the absence of certain specific secretions, the growth of the various organs would continue far beyond the normal limits. There is no reason, he thinks, why the principle should not be extended to the race; and it might be possible to explain the growth of the organism as a whole, and of its various organs beyond the limits of utility, as an indirect result of natural selection. When a useful organ begins to develop and take on some new function for which an increase of size would be advantageous, natural selection would favour those individuals in which it grew most rapidly and attained the largest size in the individual lifetime. If growth were normally inhibited by some specific secretion, natural selection would favour those individuals in which the glands producing the secretion were least developed or least efficient; and, this process being repeated from generation to generation, those glands might ultimately be eliminated or might cease to produce the particular secretion. Is it not, therefore, possible, he urges, that, the normal checks to growth being thus removed along certain lines by the action of natural selection, a definite direction might be given to the course of evolution which the organism would

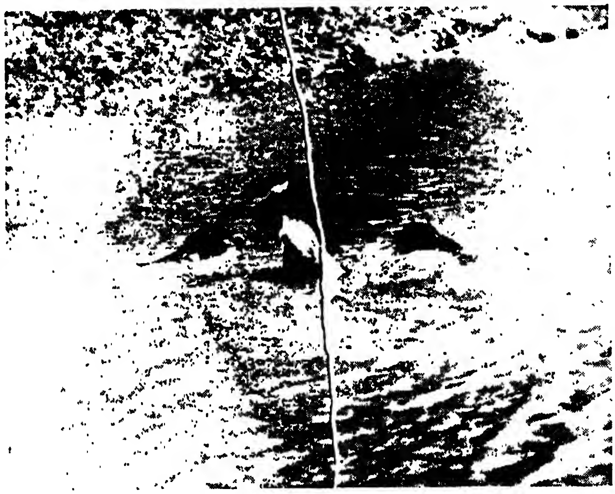
THE URSINE TREE-KANGAROO

continue to follow to the bitter end, irrespective of natural selection?

The theory is highly suggestive, and, if tenable, throws light on one of the greatest mysteries in the story of animate creation. For though we have the whale, the sea-elephant, the hippopotamus, the rhinoceros, the crust of earth, in the Old World and the New, is a charnel-house of bones that once were giants exceeding in size any living thing of our day, the biggest whales alone excepted. And in this theory may lie the clue to the disappearance of Australia's mighty beasts, where, apparently, every condition was favourable to their possessing the land down to the coming of man.

We must leave it at that, and turn to a consideration of types still in existence. The order has branched out into so many lines of life as to suggest that Nature wished to experiment with marsupials just as with the higher mammals. In the great kangaroos we have purely herbivorous animals which take the place of the ruminants; in the smaller animals we have savage carnivores in the thylacine and Tasmanian devil. We have tree-climbing animals with prehensile tails, denizens of the rocks, burrowers, and adepts at that form of parachuting which we are compelled to term "flying." Further, we have marsupials dependent upon insects for their food; and there is one, the yapock, or water-opossum, which has taken to a semi-aquatic life, and is as much at home in river or lake as an otter. We have wolf-like animals, cat-like animals, rat-like, mole-like, bear-like, rabbit-like, mice-like animals; animals out-topping a man; animals tiny as a field-mouse. And all are marsupials.

At the head of the list come the kangaroos and their allies, highly specialised in regard to their characteristic leaping progression. This is effected by the remarkable development of the hind limbs, though this feature is less pronounced in the tree-kangaroos. For the rest, the hind legs are of extraordinary length and stoutness, enabling the animal, when in flight, to progress, not on all-fours, but by prodigious leaps of twenty and thirty feet at a bound. Added to great muscular development in these limbs, it is to be noted that the bones here are of an ivory-like density, to withstand the heavy strain and shock to which these sole organs of progress are submitted. For, be it remembered, the fore legs, like the prodigious tail, are never used as a means to locomotion, unless the animals be moving slowly, when feeding. The fore limbs are weakly developed, and are used as hands. When engaged in combat in the mating season, the males spar with their hands preparatory to making an opening for a leap upon the enemy, when they bite fiercely with their teeth and strike with their powerfully clawed hind legs.


A KANGAROO IN A RIVER KEEPING DOGS AT BAY

When hunted by dogs, the kangaroo takes to water, if such be available, and, so quick is a dog to learn that if there be any depth of stream, he dare not approach, for with all the stupidity of his brain the kangaroo has learned that by using his fore paws as hands he can clutch the dog and thrust it under water and keep it there until it drowns. In our photograph the kangaroo is standing in water 4ft. 6in. deep, and it will be seen that the dogs are swimming round, not at him. When lassoed and brought ashore the kangaroo proved to measure, when standing erect, over six feet in height, while the tail was over four feet long. The kangaroo, when alarmed, raises itself on the tips of its hind feet, supported by the tail, and so commands a wide view of the surrounding country.

The food of the typical kangaroo is pretty much that of the sheep, but as an adult kangaroo of size eats as much as three or four full-grown sheep, kangaroos are being rapidly exterminated near all settlements. Indeed, there is a price upon their heads; and a few years ago, when the

ARBOREAL MARSUPIALS AT HOME

A SUGAR-SQUIRREL PARACHUTING

AN AUSTRALIAN OPOSSUM—RIVER VARIETY

A SILVER-GREY RING-TAILED OPOSSUM CARRYING HER YOUNG ON HER BACK

AUSTRALIAN OPOSSUM—HILL VARIETY

A BROWN VARIETY OF RING-TAILED OPOSSUM

"boxing kangaroo" craze spread over the country, sixty pounds and more was vainly offered in Europe for adult specimens of the big grey or red animal.

The nursing habits have already been described, but it may be added that the young are sheltered in the pouch long after they have ceased to need the nursing care of the mother. A young kangaroo weighing three or four pounds will tumble into this unique retreat at the first sign of danger, and the mother will flee with her offspring in her pouch until she can no longer carry her burden. Then she will deposit her young one on the ground, and scurry from it, not to desert it, but to lead the hunter from her little one, returning to find the latter after she has thrown the pursuer out of the chase. The young kangaroo has meantime lain snugly hidden, with the same skill which distinguishes the fawn when the doe is absent.

The wallabies do not differ greatly from their kin, the true kangaroos. They are smaller, of course, but vary considerably in size, some of them being no larger, when full grown, than a hare. While kangaroos frequent grass-land and open forest, the wallabies affect the dense bush, though the rock-wallabies, as their name implies, are to be found only in rocky areas. The tree-kangaroos, which may now be studied in the London Zoological Gardens, are thought to have taken late in the story of evolution to an arboreal habitat, since, though they leap with great boldness from considerable heights to the ground, they climb very laboriously. But the approximate equality as to length of fore and hind limbs shows that the transition cannot have been swiftly effected.

THE KOALA OR AUSTRALIAN NATIVE BEAR

As we have marsupials resembling hares, so we have kangaroos closely resembling rats, some with furry, partly prehensile tails, some distinguished by brush tails. The place of these latter animals is taken in Tasmania by the jerboa kangaroo, a much larger animal, with the tail tuft scantily developed. All told, there are close upon two score species of the kangaroo and kangaroo-like animals, and the musk-kangaroo connects the remotest kin of the true kangaroo—the kangaroo-rat—with the extensive family of phalangers. Here we have no fewer than thirteen genera, embracing animals of surprisingly varied characteristics, yet agreeing in the thick, woolly nature of the coat, in the equal length of the limbs, and in the possession of a nailless toe or finger upon the hind foot, opposable to the other digits. With few exceptions, the members of the family have long, prehensile tails.

In this family occur the so-called flying animals. First to be noted is a shrew-like creature, the long-snouted phalanger, a true marsupial, yet in outline startlingly suggesting the form of our common little insectivore. This phalanger is an insectivore, too, and from its small mouth a long, sticky tongue is protruded at will for the capture of its prey. The cuscuses follow, animals of the size of cats, passing their lives in trees, where foliage is the main diet, supplemented by birds and other small living prey. With these animals the tail is a powerful grasping organ, but in spite of its aid the cuscus, though purely arboreal, is a slow, if sure, climber. Like nearly all the marsupials, it is very tenacious of life. A kangaroo will

A CARNIVOROUS MARSUPIAL—THE THYLACINE, OR TASMANIAN WOLF

escape with its chest gorged with blood from a bullet wound, or with its two hind legs broken; and the cuscus survives for hours even the breaking of the spine or a shot through the brain.

The Australian opossums are wrongly named; the true opossums are restricted to America, but there is no better title than that applied by the people of Australia; and the naturalist is driven to adopt it as a subtitle to the general name of "phalangers" which covers the whole. There are ten genera of these so-called opossums widely distributed over the Australasian region, and common to practically all forests and scrub lands. Here we have three groups of "flying" animals, allies of as many non-flying groups. The largest is the taguan flying opossum, differing from other opossums only in respect of the membraneous parachute by means of which it makes the flight already described. This animal measures twenty inches from the tip of the muzzle to the root of the tail, but the flying marsupials range through many sizes down to that of the pigmy flying opossum, whose body-length is only a little over two inches, while a median position is occupied by the sugar-squirrel, as the squirrel flying opossum is called in Australia. This expert little aeronaut has a body-length of some nine inches. The last-mentioned animal is described as making, under stress of pursuit, enormous flights through the air from tree to tree, and protecting itself from shock, when compelled to touch ground, by a slight upward swoop at the end of the flight immediately before alighting. Its diet comprises leaves and buds and insects. There is one flying opossum, however, Leadbetter's, which performs its aerial leaps without the aid of a parachute; and this animal, it is held, is a representative of the parent form from which the opossums with flight membranes developed. The pentailed opossum "flies," too, without a parachute, and is regarded as the descendant of the form from which the pigmy flying-opossum is derived. A wonderful chapter in the story of evolution is thus preserved for the careful student.

EMBODIED FEROCITY—THE TASMANIAN DEVIL

The koala, or native bear, is the one phalanger lacking a long tail. In general outline it may be held to suggest its ursine namesake, but modern opinion inclines to regard this curious animal as a primitive form of wombat. In size it certainly agrees with the wombat, having rather the dimensions of a large poodle than that of even a quite small bear. Although mainly arboreal in habit, the koala descends at night to dig for roots, though its diet

consists in the main of leaves. A curious feature of this animal is the cheek pouches which it has developed for the storage of food, processes resembling those of monkeys and certain rodents. In carrying its young upon its back, however, it has a point in common with the true opossum, though with the difference that the young opossum coils its tail round that of its dam, which the junior koala is unable to do.

The wombat more nearly resembles the bear than does the so-called native bear. Squat, powerfully built animals, the wombats might readily be mistaken for diminutive bears, but on closer examination it is found that in point of dentition they approximate more closely to the rodents. They are exclusively herbivorous; the stress of life has driven them to burrow underground for safe homes, and they are nocturnal, as, indeed, are practically all the marsupials. The bandicoots, interesting to naturalists for considerations already mentioned, are one of the plagues of the colonist, because of the extent to which they eat his seeds and bulbs and roots. The majority of them dwell in holes in the earth, but some make nests, a practice invariably followed, among others, by a remarkable species, the pig-footed bandicoot.


THE HAIRY-NOSED WOMBAT

Turning to the carnivorous marsupials, we reach stupidity and ferocity embodied in the thylacine, or Tasmanian wolf. Though superficially resembling the true wolf, it is in reality infinitely removed from actual relationship. We have here a good example of parallelism, not relationship. The general features of the carnivorous wolf common to both, as has been pointed out by Sir Ray Lankester, have been gradually and independently arrived at in the two different and completely separated stocks; and the appearance, ways, and movements of the thylacine suggest the fancy that it is a kangaroo masquerading as a wolf. But its rapacity is not simulated; the Tasmanian wolf is the worst foe that the sheep-breeder has to fear. Relentless war is therefore waged upon it; and unless some sanctuary can be reserved to it, the animal is bound shortly to be exterminated.

The Tasmanian devil runs the thylacine close in point of destructiveness and stupidity, and is unrivalled for vice and quarrelsomeness, hence its name. Matching a badger in size, it has the true plantigrade gait of the bear, is nocturnal and a burrower, though content to avoid the labour of home making if a cave or cleft in the rocks be available. This is another of the animals living threatened lives; and unless steps be taken for their preservation, posterity will be deprived of these two brutally fascinating examples of carnivorous mammals at their lowest stage of development.

We must pass over the marsupial cats, which seem to take the place of the martens; and we can only refer in passing to the pouched mice, tree-haunting insect-eaters, which appear to take the place of the tree-shrews. Like the true mice, they are more prolific than other animals. Marsupials generally produce few at a birth, or the marsupial pouch would be insufficient as a nursery, but some of the pouched mice are believed to have as many as ten young at a birth, for ten teats are found within the marsupium. Equally brief reference must suffice for the banded ant-eater, a marsupial lacking the external pouch. The young are attached at birth to the teats of their dam, and lie concealed among the dense fur with which the abdomen is clad. This curious animal has an extremely elongated muzzle, and a long, worm-like tongue resembling that of the true ant-eater, and, like that animal, depends for


THE RABBIT-EARED BANDICOOT

its food upon ants and termites. Moles are represented by the pouched mole, of habits akin to those of the true moles. With apparently sightless dots, deep-set in the skin, for eyes, this animal is equipped with a definite arrangement of cells upon the skin of the head, on the rump, and on the pouch; and these cells are believed to act as a sense-organ of touch, as compensation for loss of sight.

The only marsupials remaining in the world beyond Australasia are the selvas of tropical America and the opossums of Central and South America, with one species of the opossum ranging north as far as the United States. They take the place in South America of the insectivores, and are all carnivorous; all possess a grasping organ of great sensitiveness and strength in the tail; all are arboreal in so far as a resting-place is concerned; and all are famous fur-bearer. This animal attains a body-length of twenty-two inches, and the tail is fifteen inches. There is one species, the mouse-opossum, that is really as tiny as its name implies. while the three-striped opossum is only four or five inches in length. One species of opossum in Argentina has taken to life on the treeless plains, the notable exception to the rule as to the arboreal habits of the genus. This is the yapock, already noted. It lives upon small fishes, crustaceans, and the like; and, the better to qualify for an aquatic existence, has developed webbed feet, and in general habits is a close imitation of the otter.

Though the marsupalian is a large order, there is not a brain worth mentioning in the whole series. The opossum brain, if not the most highly organised, is certainly put to the best use, a fact clearly attribut-

THE TRUE OR VIRGINIAN OPOSSUM

THE YAPOCK, OR WATER-OPOSSUM

nocturnal. Those which lack the marsupial pouch carry their young at first simply attached to the teats, where they cling with great tenacity. Afterwards the little ones are transferred to the back of the mother, and there they twist their small tails around hers, curved forward for the purpose.

It is an object-lesson in adaptability to see the female of either the philander opossum or the woolly opossum speeding through the greenwood, high above the ground, each with perhaps a dozen little ones riding on her back, their tiny tails clinging like creepers to hers, and their little paws clutching the ample fur of her back. The best known of the genus is the Virginian opossum, a notorious robber of nen-roosts, ranging from Argentina and Paraguay to New York, and a able to the struggle for existence in a sphere crowded with many and varied forms of life. The power of the opossum to "feign death," and endure frightful torture before creeping away as soon as the vigilance of the hunter is relaxed, has been counted for intelligence. To "play 'possum" is represented as the acme of cunning. But latterly inquiry has rather tended to show that all this "feigning death" by animals may be no deceit at all, but the outcome of temporary paralysis and insensibility induced by acute fear. This really seems more feasible than that an opossum should wittingly submit itself to be almost flayed alive without moving a muscle rather than make one dash for liberty. Insensible endurance is to be expected of a marsupial, for, next to a reptile, it is the hardest of animals to kill.

THE MIND THAT PERCEIVES AND ACHIEVES

What happens when we think is beyond the wit of man to understand, but this picture shows, in a very simplified form, something of the action of the brain of an artist as he paints a landscape. An inconceivable number of messages must be flashed from brain-cell to brain-cell to initiate man's smallest creative action.

WHAT BRAIN-STUDY SHOWS

The Astonishing Foldings of the Brain and the Activities Traced to Each

THE SWITCHBOARD THAT LINKS UP THE MIND

If we weigh the entire brain, we find that the comparatively new development, called the cerebrum or great brain, comprises six-sevenths of the total weight. Of all this substance, however, only the much-folded surface really concerns us. As regards the folding of this bark or cortex of the cerebrum, we observe that it enables the cortex to have really no less than five times the area of the cerebrum taken as a whole. No wonder, therefore, that there is some relation between the degree of folding in different brains and the quality of their manifestations. But it is also to be noted that this method of folding the cortex is much better than merely thickening it would have been. Keeping the cortex thin, and folding it, had the advantage of enabling the nerves to get at it readily on its inner surface, and of enabling the tiny, innumerable blood-vessels from the innermost of the brain coverings to reach the cortex liberally and easily from its outer surface. It is to be remembered that the innermost brain membrane, the *pia mater*, dips into the fissures of the cerebrum, and thus follows the cortex in all its foldings.

Though every brain differs in the very small details of its surface pattern, yet the main unfoldings of the cortex are fixed in mankind, and are unfailingly transmitted by heredity in all normal brains, in every race everywhere. It thus becomes possible to prepare an average or constant map of the cortex, showing its division into a small number of lobes, having deep and constant fissures between them, and showing how each of these lobes is itself fissured, on the whole, in a constant way. Such a map of the left side of the cerebrum is shown on page 1901, with the frontal, parietal, temporal, and occipital lobes clearly displayed. Each of these lobes corresponds, roughly, to the similarly named bones of the skull, shown on page 820. The importance of this preliminary mapping out of the cortex is extreme, for once we have gone so far, and find how constant are its main features, we find ourselves asking again the perfectly reasonable questions which were asked by Dr. Gall, the founder of phrenology, such a long time ago, and to which, in the state of knowledge at that time, only erroneous answers could be made.

In a word, we feel assured that there must be, in the brain as everywhere else in the body of man, or of any living creature, some correspondence between structure and function. May we not, for instance, be able to show that the occipital lobe is concerned with, say, vision, the temporal lobe with hearing, and so on? This is the great problem of what is now known as "cerebral localisation," the attempt to localise the performance of certain functions in certain fixed and identifiable parts of the cortex. For this purpose we must, of course, consider the whole cortex, not only the outer surface, as shown in the illustration, but also its inner suface, which we see when we part the two hemispheres of the cerebrum, and look between them.

Our inquiries exceed in importance, for practical purposes, almost any that can be named, and for philosophy they far transcend anything else that science can attempt.

Their practical value is that, when a man suffers from particular disturbances of vision, say, or from a particular paralysis of a leg, we may be able, by means of cerebral localisation, to infer that a particular area of his brain is being disturbed. No external sign whatever will be present, yet the surgeon will be justified in removing a portion of the skull, which he knows to be just over a certain area of the cortex, and he may then find a tumour, an abnormal thickening of bone or of the membranes of

the brain, or even some parasitic invasion, which he can remove, thus curing or greatly relieving his patient. The greatest surgeon, living or dead, in this field is Sir Victor Horsley, and his own researches upon brain localisation are among the most valuable of the many which have now placed the subject on a firm foundation.

As for philosophy, clearly no researches in the sky, nor in the rocks, nor within the atom can compare for a moment with researches into the functions of those particular combinations of atoms and molecules which constitute the cortex of the human brain, and serve as the organ of the human mind. The mind of man is so much the highest thing we know that nothing else is to be named beside it; our supreme questions, of God and Immortality, centre in the mind or the soul of man; and the *cortex cerebri* is its instrument, so much so that if we crush it, or poison it, or blow it into grey mud with a pistol shot, there is the earthly end of the soul. Evidently, nothing with which Science can concern herself compares for a moment with the *cortex cerebri*. And in the nineteenth century science won amazing successes in this field, definitely localising certain functions of the mind in certain sharply limited areas of the cortex; so much so that the doctrine called materialism seemed to be triumphantly vindicated, and the brain was said to secrete thought "as the liver secretes bile." Plainly we must look into this with the utmost scrutiny.

The Relation Between the Brain and the Power of Speech

The famous French anthropologist Broca began by finding that destruction of a certain small area of the cortex in the frontal lobe of the cerebrum on the left side resulted in entire loss of the memory of words in a right-handed person. Thus we now speak of "Broca's convolution" and of the "speech centre." We know, also, that the speech centre is always to be found in the "leading half" of the brain—that is to say, the right half in a left-handed person, and *vice versâ*. (We remember that there is no puzzle here, for the fibres from the cortex cross over in the lowest part of the brain, on their way to the body, and thus either half of the brain corresponds to the opposite half of the body.) We know, further, that if the speech centre be damaged in very early life, say, at three or four years, it is not a very difficult matter to make a fresh start, and teach the undamaged area in the right half of the brain, if the child be right-handed, and the damage has been done on the left side of the brain. But in late life, when the rupture or blockage of a blood-vessel has destroyed the action of the speech centre, and, as often happens, has also paralysed more or less of the right half of the body (in a right-handed person this would be), we find that the attempt to educate the corresponding area on the right side of the brain is almost hopeless. A few words may remain, having been learnt by both sides of the brain, but they will be very few—as a rule only "yes" and "no" and other simple terms which have become largely mechanical.

The Brain Centre for Written Speech Not the Same as for Spoken Speech

If we ask why speech or language should be specially associated with this particular area of the cortex and no other, we simply find that this is the area which corresponds best to the movements of the tongue, lips, and jaws and palate, that are concerned in speech. In other words, it is only spoken speech that is represented here, and we must look elsewhere, though not far, for written speech. We find, also, that where more languages than one are spoken, each language appears probably to have a little area of the cortex to itself. But, indeed, many a large volume is devoted wholly to the speech functions of the cortex, and we can go no further into the more dubious matters here. Yet we have already noted a fact which leads us far—that the motions of certain parts of the body are represented in the cortex. Naturally the inquiry proceeds with this clue, and we soon find that *voluntary* motions of all parts of the body are sharply and constantly represented in the cortex. The "motor centres" are found on the outer side of the brain, grouped round the deep and constant "fissure of Rolando," so that this is often called the "Rolandic area," including part of the frontal lobe, in front of that fissure, and part of the parietal lobe, behind it.

The Motor Areas of the Cortex Used for Co-Ordinating Groups of Muscles

But we must no longer call this the motor centre or area, for the brain and the spinal cord have many other motor centres and areas, and motions of all the voluntary muscles in the body can be initiated without invoking any part of the cortex at all. The cortex is a new formation, and it stands for will and purpose. The only proper name of this area is not motor but psycho-motor, to indicate its real status.

We might suppose that such a great muscle as, say, the biceps of the arm

would be represented in this area, but we are wrong. The biceps, and every other muscle, has a nerve supply which can be traced to definite centres in the brain or spinal cord, but no muscle whatever is represented in the cortex. The psycho-motor area of the cortex is concerned not with individual muscles, but with co-ordinated and balanced groups of muscles, urged as a whole for the performance of definite, purposeful movements. The psycho motor centre is the controlling mechanism of a being who uses his body and its parts for purposes, and thus achieves them. It follows that you can voluntarily bend or extend your arm, or perform any other movement you please, but it is a physical impossibility for any man to stimulate his biceps, or any other single muscle, by means of his will. In fact, every willed movement involves not merely the stimulation of certain muscles to perform it, but also the stimulation, and sometimes the forbidding, of certain other muscles, which have the opposite action.

The Cells that Feel Sensations and Those which Initiate Voluntary Movements

The balance of the whole, initiated in the cortex, and in the cortex alone, achieves the movement, and accomplishes the purpose, but it is only when we observe the results of disease, either of the cortex or of the centres below, which it controls and balances, that we realise how amazing and indispensable its functions are for movement that shall be anything but unmanageable spasm.

There is more, however, to say about this psycho-motor area. The photographs on pages 62-3 of this work show that certain layers of the cortex in this region are characteristic, containing the very large cells of pyramidal shape which are definitely associated with voluntary movements. But though those cells are characteristic of this area, being found nowhere else in the cortex, they do not comprise the whole thickness of the grey matter in this region. There is something else to reckon with, and that is what we call " common sensation." The cortical centre for " common sensation " so-called—touch, temperature, and pain sensations being included in that term—was long sought in vain, until at last the localisers found that it coincides with the Rolandic area. In other words, this is a ***sensori-motor area***, in which, cheek by jowl, and in the most intimate relation by means of their " dendrons," are found both the cells which feel these sensations derived from the skin, and the cells which initiate voluntary movement. Thus the machinery suits the need, as when, for instance, we remove the hand from a hot surface, or return the hand to a pleasant surface, the sensation and the corresponding movement have their seat in one and the same area of the brain.

The Size of the Motor-Areas in Relation to the Complexity of Movement

But though this area is large, it only comprises a small fraction of the whole cortex, and there is much more yet to account for, though we cannot leave the Rolandic area finally without noting the results of comparative research in many animals—that the size of the area for any particular movement is proportional to the complexity of that movement. Thus the arm and hand of the ape have far larger cortical representation than has the foreleg of the dog, though the muscles are equal in size in the two cases. And in no other brain is there anything parallel to the liberal cortical area which, in the brain of man, corresponds to his hand, and, above all, to his thumb. But we must pass on, for though we have localised voluntary movement and common sensation, which are certainly paramount, vision and hearing, to mention nothing else, remain. Here, as in the localisation of common sensation, we owe much to the classical researches of the great Scottish investigator Sir David Ferrier.

We now know that the cortical centre for hearing is in part of the temporal lobe. But again there is crossing over of the nerve fibres, so that the cortical centre for the right ear is in the left temporal lobe or *vice versâ*. Here complications are endless.

The Areas of Hearing and Understanding Are Neighbours, But Not the Same

Hearing is one thing and understanding is quite another. We find that there is a cortical centre of sheer hearing, but that there is another, adjacent but distinct, in which reposes our appreciation of the meaning of words. Often we hear and say, " Beg pardon ! " not having really attended, and then, a little later, we understand. In the first stage, the hearing centre was at work ; in the second stage, the understanding centre also came into action. Similar complications to what we have already seen also arise here in relation to the understanding of different languages—not least of the " universal language," which is music. Probably there is a quite definite music centre, close to, and presumably a

specialised part of, the ordinary hearing centre. But here, as in many other problems of cerebral localisation, we shall never get much further until critical comparison has been made of the brains of musical, non-musical, and tone-deaf persons, as well as of great composers. For this purpose, as for many others, science requires the state of public opinion and cultivated altruism which has already induced a very few distinguished men to bequeath their brains for the purpose of science.

How the Real Eyes of Every Man are in the Back of His Head

Meanwhile, we must proceed to the case of vision. Here the cortical area is found to be in the occipital lobe of the brain, and at its furthest back portion; so that the real eyes of every man are in the back of his head. And in this instance, as in others, comparative anatomy shows how vision has been promoted, asked to go up higher, in the course of organic evolution. Even among insects, which have no real brain, we find large collections of nervous matter, which we call optic lobes, and which are associated with vision. The brain of the fish practically consists of little more than such optic centres. But when the cerebrum develops, the centre for vision is slowly transferred to it. In the lower mammals, this transference has partly occurred, but even such a high mammal as the dog has not the whole of its vision-centre transferred to its cortex. In the anthropoid apes and in man, however, the transference is complete. We see with our cerebral cortex alone. All the older structures remain at the base of the brain, and the nerves from the eyes visit them; but they only survive for old sake's sake, so to say, and the cortex has taken over all their functions, and discharges them a thousandfold better than ever before.

No Sight of the Lower Animals Compares in Complexity with that of Man

The reader may be inclined to measure vision in terms of ocular acuteness, and will naturally question the asserted visual supremacy of man over, say, the hawk, or many other animals. The real tests, however, are perception, comprehension, discrimination, memory, visual synthesis and symbolism, as in associating sounds and meanings with certain visual shapes, which we call reading; and here man is pre-eminently first. The visual area of his cortex has no animal parallel for extent, and for the variety of its cells.

When it comes to the sense of smell, however, man is found to be degenerate. This sense has its cortical representation on the inner aspect of the temporal lobe, which is only to be seen when the brain is parted down the middle. This area is as inferior in man to the corresponding area in the dog as the visual area in man is superior to that of the dog. The familiar facts of the sense of smell, in the two creatures respectively, correspond exactly to what we find in the study of the cortex. The dog lives largely in a smell-world, man largely in a vision-world. In man, and in his more immediate ancestry, the sense of smell has long been decadent, simply because the sense of vision was found to be so immeasurably better worth development. Thus the dog only bays the moon, while man has measured the altitude of its volcanoes; the dog has never noticed Sirius, and man knows its mass and chemistry. And we need only remind ourselves of the developments and possibilities of vision in terms of art and of geometry in order to understand why man may be content that his sense of smell, a mere contact chemical sense, and very rapidly fatigued into the bargain, so that we cease to smell in a few seconds, is decadent beyond repair. He has bargained well. As for the relatively trivial sense of taste, its cortical representation is not far from that of the sense of smell.

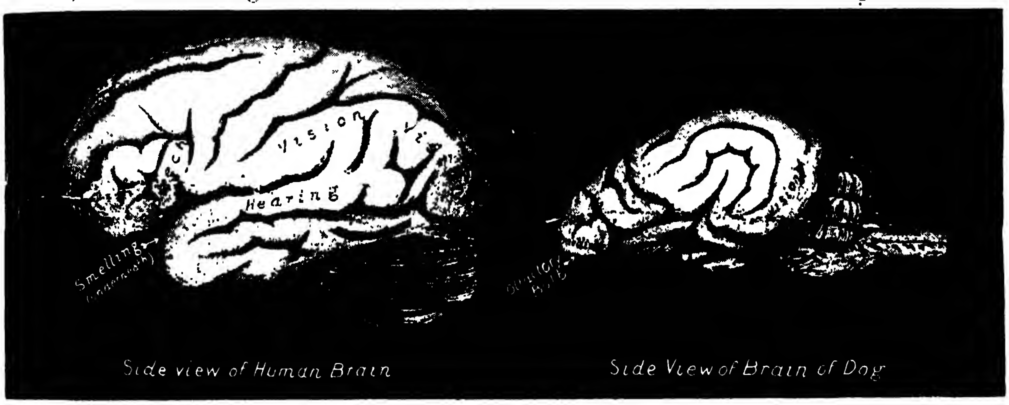
The Silent Areas of the Brain and their Probable Concern with "Association"

Having thus accounted for motion and sensation, we might suppose that the whole surface of the cerebrum would now be mapped out, but that is far from being the case. Even now, the greater part of the cortex remains unaccounted for, and we have no definite functions to seek a place for. Or, rather, we have all those functions which involve more than either sensation or motion, all the higher functions of intelligence. Primarily, these functions depend upon the power of association, or "putting two and two together." We may therefore suspect that association is the true function of those silent areas of the cortex, as they have been called, which yield no answer when we inquire of them, and produce no results when they are locally stimulated or irritated by disease or injury. Very important and suggestive facts are yielded by special study of these silent areas. The cortex here is no less thick, no less richly supplied with blood-vessels, no less abundant in nerve-cells, than elsewhere. If we compare the brain of man with those of a

series of the lower animals, and place them in the known order of intelligence, the results are very striking. As intelligence, association, the power to put two and two together, or to *learn*, and find out, increases in the scale, so the cortical area as a whole increases; and certainly part of this increase is due to the fact that, for instance, the centres of vision and hearing grow larger. But the enlargement of the areas with known functions of motion or sensation only accounts for a small part of the total extension of the cortex with increasing intelligence. Much the greater part of the development is in these "silent areas," which seem to have no functions at all. Indeed, the growth of the cortex, compared in an ascending series of brains, appears mainly to consist in a development of surface between the areas of sensation and motion, ever thrusting them further and further apart, so that in the lower brain they lie beside one another, and in the brain of man they are mere patches upon a chiefly unallotted surface.

This can only mean that, somehow or other, these areas are connected with the development of intelligence; and there is another piece of evidence. Dr. Hughlings Jackson taught that the nervous system consists of a series of levels, superposed upon one another, the highest being the latest in order of evolution—a fact which we recognise when we speak of the cortex as the neo-pallium, or new mantle of the brain. We further observe that structures which have developed last in the history of the race also develop last in the history of the individual; and finally, that structures which were "last to come" in the history of the individual or the race are the "first to go" when the individual is being broken down by poison or old age. Observe now that these silent areas of the cortex show their comparative youth, even when compared with the rest of the new mantle itself. We have seen that, in the evolution of the race, they are the last to appear. So also is it in the evolution of the individual. These areas are "last to come," as is proved by the fact that the nerve-fibres running from the cells of these areas are the last in the whole nervous system to acquire the sheaths which isolate the nerve currents, as we suppose, and which must be formed before the nerves can perform their functions. Finally, in decadence of the individual, there is some evidence to show that these parts of the nervous system, last of all to come, are the first to go.

These unmapped areas of the cortex are therefore to be looked upon as its latest and highest parts; and we must trace the bundles of nerve-fibres that proceed from them, in order to see whether they perform the functions which we suspect. At once we find that these fibres run to and terminate in *other parts* of the cortex and the brain in general, notably including the cerebellum. Further, we find strand upon strand of nerve-fibres proceeding from the cells of the sensory areas to these silent areas, and ending among the cells there. The evidence is therefore conclusive that these "silent areas" of the cortex, which are the most characteristic parts of the entire physical structure of man, are indeed association areas, and that they must be concerned in all those processes of examination, recognition, and association of sensations, and the building up of mere crude sensations into true perceptions, which lie at the basis of all intelligence. It therefore becomes of high interest to trace these association fibres as closely as possible, and to see in what visible physical ways they bring the



THE BRAINS OF MAN AND DOG COMPARED, SHOWING AREAS OF SMELL AND VISION

various definable areas of the cortex into relation.

The reader may possibly have been asking for a modern answer to the old question whether the frontal lobe is the seat of the intelligence, it being well known that the frontal lobe of the brain has a most remarkable development in man, as we recognise whenever we use such a phrase as "his noble forehead."

The Brain not Dependent for its Intelligence on Any One Lobe

The answer is involved in what we have already argued. There is no lobe of the brain that is the seat of the intelligence. The whole of the cortex is concerned in intelligence; and its efficiency for this purpose must depend, first, upon its unparalleled extent in man; and, second, upon the amazing perfection with which all the parts of the cortex are brought into close touch with each other by means of the association system of the cerebrum. That association system, which is the narrowest term of physical structure within which we can pretend especially to confine the intelligence, has its cortical centres all over the surface of the brain. True, the frontal lobe makes a very large contribution to the whole, and thus the close relation of the frontal lobe to intelligence cannot be denied. But exactly similar cortical centres of association are to be found, in wide extent, in the parietal lobes, for instance, and in all parts of the surface of each half of the cerebrum, both outer and inner. All these areas together must be reckoned the special seat of the intelligence, if we are to name as such anything less than the united, associated, exquisitely unified whole which we call the cortex cerebri.

The Importance and Number of the Association Fibres of the Brain

That cortex is only about one-eighth of an inch in thickness. Its cellular contents have long been studied by the microscope, of which the latest and best results are reproduced photographically on pages 62-3 of this work. Nothing can be here added to what those photographs demonstrate. Only we can observe that every part of the cortex is connected, directly or indirectly, with every other by means of association fibres, both leaving it and coming to it. We find short association fibres that connect adjacent convolutions of the brain, and longer strands which run between the various lobes of either hemisphere. And we further find certain very numerous and conspicuous groups of association fibres, usually called commissural, which travel across from one cerebral hemisphere to the other. Most notable of all these, and of steadily increasing importance in the mammalian group of animals, culminating in man, is the *corpus callosum*, an almost numberless bundle of nerve fibres that have their origin in the various cortical areas of one or other hemisphere, and are travelling to the opposite hemisphere, there to end somewhere around the bodies of its cortical nerve-cells.

So much, then, for the physical structure of the cortex. We may pursue the details indefinitely, always tracing the nerve-fibres from its various areas more and more accurately, and we may expect, by refined methods, to see more and more detail of its nerve-cells. There is also an infinite field for future study in the comparison of the cortex of different brains, first as regards the different races of men, but above all as regards the special powers possessed by exceptional individuals.

The True Relation Between Animal Mechanisms and the Human Will

In this direction it is just to say that at present we know nothing, and that there must surely be most important and remarkable results to obtain, when opportunity offers. But no matter how perfect our methods, nor how many brains, of common people, and men of genius, and lunatics, of all races we examine, the cortex cerebri will never yield us more than the physical structures which we already know. Nerve-cells and their processes are the beginning and the end of the whole story.

It only remains for us to try to interpret the functions of the human cortex cerebri in terms of what we observe in the behaviour and personal conduct of man. We must cease to suppose that, under the microscope, we shall ever find mind visible, for that is to misunderstand the nature of mind. But we may certainly try to express the true and characteristic functions of the cortex as the supreme organ of mind; and here Bergson will help us, having carried the philosophic interpretation of scientific fact in this direction a stage further than anything that was possible for his predecessors.

In all the levels and parts of the nervous system, below the cortex itself, there exists the apparatus for a number of motor mechanisms, as, for instance, swallowing and walking, which are either ready made, or easily put together in the developing nervous system, and which, at a signal, will always set to work and perform the

particular act which corresponds to them. The will is employed, sometimes in constructing the mechanism, as when we learn to walk or play the piano, and at all times in choosing the mechanisms to be used, the manner of combining them, and the moment of their employment. In Bergson's words: "The will of an animal is the more effective and the more intense, the greater the number of the mechanisms it can choose from, the more complicated the switchboard on which all the motor paths cross; or, in other words, the more developed its brain. Thus the progress of the nervous system assures to action increasing precision, increasing variety, increasing efficiency, and independence. The organism behaves more and more like a machine for action, which reconstructs itself entirely for every new act, as if it were made of indiarubber and could, at any moment, change the shape of all its parts."

The Bark of the Brain the Switchboard of the Sensations

From this point of view, then, which is concerned with the cortex in relation to action, we may compare it to a switchboard, where all the paths of sensations, and all the paths of possible movements, cross, and can be connected. We have already seen that, first by means of its allotable areas, where all sensations and movements are represented, and then by means of its association areas, the cortex of the human brain answers beyond all imagining to this idea of an incomparably complicated switchboard, the ruler of which, the will, can use it for all and every purpose. This cortex is the switchboard of a creature who is, above all, a centre of action. The nervous system beneath the switchboard marks out the possible lines along which action can run. But there is choice between them, and above all is there choice between them in the case of man. Choice and consciousness go together—the greater and more real the choice, the more intense the consciousness; and since man has the amount of choice represented by the amazing possibilities of the "switchboard" we call his cortex, consciousness reaches a unique intensity in him. Thus it looks, at first, as if consciousness flowed from the cortex, but that is a false statement of the relation between them, which Bergson has thus admirably stated: "In reality, consciousness does not spring from the brain, but brain (*i.e.*, cortex) and consciousness correspond because equally they measure, the one by the complexity of its structure and the other by the intensity of its awareness, the quantity of *choice* that the living being has at its disposal."

In all these associated respects man is unique. The difference between his brain and even that of the anthropoid ape is such that it is really a difference of kind. Up to and including the ape, the cortex of the brain has never been able to do more than set up a limited number of motor mechanisms, according to the structure of the creature's body and nervous system, and then it chooses between them.

Man's Life, which is Mind, Becomes Aware of Itself Through Choice

But the brain of man differs in that its power of constructing machinery for action is not limited to the body underneath the brain, but can transcend it. Man can make tools—pianos, aeroplanes, pen and ink—outside his own body, and then his will, using his incomparable cortex as its switchboard, can choose among them. In all other creatures the choice is limited; in man it is unlimited. This is the difference between the closed and the open, a difference not of degree but of kind.

Life, which at bottom is mind, always aims at freedom within and empire over the physical, which it uses as its instrument, and in which it is displayed. In man alone does this freedom realise itself, thanks to his cortex, which enables him to construct, within and without his body, an unlimited number of mechanisms, not least the mechanism of articulate speech, between which his will can choose, and in choosing and using which his consciousness is manifested—his life, which is mind, becomes aware of itself.

Man's Mind the Only Open Road of Progress that Remains

Everywhere but in man consciousness has had to come to a stand; in man alone it has kept on its way. He alone continues indefinitely forwards the eternal thrust of life; in him alone the will, which is of the very essence of life, becomes free. This is not exactly to assert "the freedom of the will," which has yet to be studied, but it asserts that the "will to live," which we now see to be the will that is part of all life, has found and made in man alone the open road. Such is the conclusion which we reach at the end of our study of his body from the physical side; and it warrants us in now passing, more humbly and more proudly, to the study of the "human mind," which is Mind as the ultimate psychic substance of life, evident in humbler forms, transcendent in man.

THE FOUNDER OF DOMESTIC MEDICINE

The kindly village wife, gathering herbs and trying decoctions of them at a venture, is the unscientific founder of the vegetable medicines so seriously discredited by modern experiments.

THE DRUG SUPERSTITION

The Ignorant and Baseless Belief of the Populace in Medicines, and Consequent Difficulties of Doctors

THE TRUTH ABOUT THE POWER OF DRUGS

The reader who thinks that the whole of health is bound up with what one swallows need not fear that we have forgotten diet and its problems, or are going to deal with them perfunctorily. But the subject is, in many ways, extremely difficult and obscure; a great many things which we had thought we knew we now see that we do not know; and the whole trend of modern physiological experiments with different forms of flour, with preparations of meat, and so on is to show that there are vast realms of dietetic physiology still unexplored. A critical volume, surveying the field, and published in the present year, leaves the reader in a state of irritable uncertainty when the *pros* and the *cons* have been impartially stated for almost every dietetic theory that has an advocate. The writer is therefore purposely dealing first with subjects which are not in this condition of rapid and uncertain development; and now that we have reached all those questions of personal choice, taste, and conduct which are concerned with what one swallows, we shall leave the more obscure and novel problems to the last, and shall begin with some matters, quite urgent enough, as to which it may fairly be said that modern physiology and hygiene have made up their minds. And first we must deal with all those practical questions of drug-taking which matter so much at the present day, and must note not only their practical importance, but also the verdict of modern science upon the use of drugs, in health and in disease.

It may briefly be said that in our own day the doctors are giving up drugs, and the public is taking them up; they are being abandoned by experience and adopted by ignorance. We speak, of course, of drugs as a whole; the few great exceptions, such as quinine and mercury and iron, will be dealt with in their place. The recent verdicts of leading doctors on this subject may fairly indicate what the best medical practice is now inclining to. More than half a century ago, Dr. Oliver Wendell Holmes, who was a wise medical observer as well as a humane and illustrious thinker, expressed in characteristic fashion the conclusion to which he had come: "I firmly believe that if the whole *materia medica* could be sunk to the bottom of the sea it would be all the better for mankind and all the worse for the sea." The words are well worth quoting and remembering, even though we remember such "medical materials" as quinine and a few more besides, which mankind would certainly be the poorer for the loss of. And, lately, Sir William Osler, Regius Professor of Medicine in the University of Oxford, has declared that *he is the best doctor who best knows the worthlessness of drugs!*

There may be readers to whom such *dicta* as these may sound outrageous, or who may be inclined to ask what the modern doctor thinks to be the use of him if he has no opinion of the medicines which he gives—pray, what is he there for at all? If such a reader were to consult such a doctor, and receive no medicine for his pains, there would certainly be trouble, and there is, in just such cases. In fact, the doctor *must* give medicines, for his patients will all leave him unless he does so. If the case is one where available drugs can be of service, well and good; but, if not, the doctor must prepare something or other, preferably with a substantial flavour and smell and colour, in order to please the patient. Such a prescription is known by doctors by the Latin name of a "*placebo*," which simply means "I will please." But it is to be observed that, in the existing state of popular knowledge, this prescription of

placebos, which is universal with doctors in all parts of the world, is by no means dishonest or illegitimate. Very often the drug does good, and is therefore justified, even though any other harmless drug would have done just the same good. The action is through the patient's mind upon the patient's body, a fact of which the patient has no idea; but a faith-cure is none the less a cure, and a much better thing than no cure at all.

How Doctors Must Accommodate Themselves to the Ignorance of their Patients

There, however, is the fact, and the sooner the public knows it the better, for a very urgent and novel reason, as we are about to see. The medical student of to-day is taught the facts about drugs so far as they are known, and the manner of using those which are useful. He learns, also, about those which are, at any rate, harmless, not least those which have marked flavours and impressive appearances. He is warned, furthermore, that he is utterly wrong if he assumes that, where there is no useful drug to give, nothing is to be given. In the first place, he will certainly lose his patient, who will go to someone else, feeling himself cheated and neglected. And, in the second place, even if he chances upon a patient knowing and hard-headed enough to visit him again, even though no medicine has been ordered, the fact will remain that some prescription or other, however inert, might have soothed and helped the patient by its effect on the mind. The sense of mystic comfort which, for most people, attaches to the taking of medicine is beyond question; and it is a fact which the really wise and humane practitioner cannot ignore, though, no doubt, such a practitioner will do his best to ensure that the patient does not neglect things that really matter, in his delight with his draught.

Will Accommodation to a Vulgar Prejudice for Medicine Continue Under the Insurance Act?

This question has never been so important as it is today. A year ago, or ten years ago, it was important for individual conduct, but today it is important also for national conduct, and that is why we must insist upon it here. The people of this country have embarked, once and for all, upon the great business of national insurance against illness. It is a superb project, and will achieve stupendous things. It is here discussed with absolute and rigorous impartiality, without any sympathy with or prejudice against any political party, any person, or class, or profession. It has been otherwise discussed; and readers might do worse than take good heed on this occasion, where the interests of science, the interests of truth, are supreme.

Now, the National Insurance Act, in this country, like the national insurance laws in Germany, though containing a variety of valuable and even glorious provisions, is also largely based upon just those ideas of the real functions of the doctor which our present knowledge of drugs will show to be worthless. It is assumed that a man falls ill, calls in the doctor, who examines him, and orders a bottle of medicine, which the patient swallows and is cured by, if he can be cured at all. One can imagine what would happen if any doctor employed under the Insurance Act, however skilful, honourable, and attentive, were to order bottles of medicine for his patients only where, in similar circumstances, he would swallow those same medicines himself. So completely ignorant of modern medical science and the laws of health and disease is practically the whole of the population of this as of every other country that such a doctor would find his position untenable within a week.

The Tragedy of Thinking That Medical Practice Consists of Giving Medicine to Ill People

Yet until these popular ideas are modified, and the public is taught to value the doctor's advice *infinitely* more than his medicine, in at least nine cases out of ten, there can be little progress in the improvement of the average standard of health. And the tragedy is that the Insurance Act, as it at present stands, goes very far to stereotype, and to stamp with the authority and sanction of the State, just those ideas of medical practice which every doctor who should not be laying bricks knows to be pernicious and obsolete. In the eyes of the Insurance Act, its authors and administrators, and the public at large, medical practice ought to be what we have just described, and can be nothing else. Medical practice means giving medicine to ill people; and if the State provides and keeps going a system by which ill people shall have medicine given to them, "national insurance against sickness" has been achieved.

Perhaps it would take the reader a decade of study of medical theory and practice to realise how intensely tragical all this is, what gigantic waste of money and life it involves, and what appalling failure to use a great opportunity. But we must do our best; and it may be by just such works

as this that we shall hasten the time when an educated public, and even an educated legislature, may be available to establish a system of national insurance against sickness on other principles, such as will surely prevail, and such as are already admirably illustrated in the splendid provisions of the present Act for maternity and tuberculosis. Undoubtedly, however, this Act, so long as it is administered in its present form, gives drugging a new lease of life among us, and renders all the more necessary as wide and early a diffusion as possible of the facts regarding drugs as they are now known to the best medical science of our day.

The Popular Consumption of Tempting but Harmful Proprietary Drugs

The importance of this subject as regards individual conduct also has never been greater than it is today, as every doctor knows. The horrible and offensive drugs used in former days were at least difficult to obtain, and had to fight against the objections entertained by the patient's nose and palate. But we have changed all that. Today manufacturers vie in the effort to turn out drug preparations of the most attractive, elegant, and tasteless kind, scarcely less tempting than sweetmeats, while the Press derives a large part of its income from advertising them. "Scarcely less tempting than sweetmeats," we said, but, indeed,one can now obtain all manner of potent drugs actually enclosed in chocolate and bonbons of various kinds. Hence the universally admitted fact that there was never before so much self-drugging as there is among civilised communities at the present. The drugs simply did not exist, or were not to be had, or cost gigantic sums, in former days. Most of the most powerful and objectionable never existed at all in any form until they were constructed, a few years ago, from coal-tar and what not in the chemical laboratories of Germany. The enormous sums spent on advertisement, the experience of retail chemists, and the records of the sums paid for Government stamps upon proprietary preparations, abundantly suffice to show the enormous quantity of drugs of one sort and another which the public stomach daily consumes.

How the Public is Led to Suppose that the Commonest Nostrums are Rare

Of course, there are very wide differences between them, and we do not here condemn them all. Some are often valuable, though most are at all times, in health or in disease, harmful, and nothing but harmful. The composition of those whose composition is secret is easily ascertainable. Most of them are very far from being as harmful as many of those which are not patent or proprietary at all. Other patent or proprietary preparations make no secret of their composition, and among these there are some which are valuable in suitable cases, and others which are harmless. But as for those whose composition can only be ascertained by reference to the analyses published in the medical papers, the public should realise that the reason for secrecy is either that the preparation contains nothing worth mentioning, and that the cost price, say ¾d., of the two-and-ninepenny bottle would be too easily calculable, or else that the preparation contains some drug which is notorious for its danger.

Of course, the view taken by the uninstructed is that the secret preparations contain some unique medicament, unknown to the medical profession, and unobtainable elsewhere—some extract of a rare foreign plant, perhaps, of which ordinary chemists and doctors have never heard. All this is sheer rubbish. There is not a single secret preparation upon the market which contains anything other than the most familiar ingredients; and though these ingredients vary slightly in the various preparations, they are usually very limited, revolving round aloes as a centre, and they have one characteristic in common, which is their universal and unrivalled cheapness.

The Taking of Poisonous Drugs a Survival of Primitive Superstition

We shall look at this matter more closely later, but meanwhile we may state the verdict of the modern hygienist upon these preparations as a whole, not least those which contain most undesirable drugs designed to act upon the nervous system, from alcohol and opium to the various modern hypnotics and "pain-killers"—which kill so much more than pain. In the whole armoury of these things there is scarcely a drug that can possibly be described as curative in any sense at all. Many of them modify the symptoms of disease, no doubt, but that is a very different thing; and any of them, if and when they are adequately believed in, may cure certain disorders, just as so much water or "Sacch. Ust."—which looks very well, but is only burnt sugar—would do in the same conditions, the patient's faith making him whole. On the other hand, it is beyond doubt that they do incalculably more harm than good, and do it at an enormous monetary cost.

The general advice of the hygienist is: avoid them all like poison—which they really are. The whole foolish business is a survival from primitive superstition, and merely suffices to show how much primitive credulity and love of magic survives in modern man. It is quite easy to avoid the imbecile habit of self-drugging, so readily approved by the man who would not dream of attempting to repair his own motor-car, which is as simple as a pin compared with the human body, but it is a most difficult matter to break the habit; and when the drug belongs to the class technically called neurotic, its chains are almost unbreakable. Pass them by, one and all, and spare your purse and your person.

So far as the practice of self-drugging, especially with secret preparations, is concerned, all sensible people will agree, but most of them will consider the case very different when the drug is prescribed by someone who knows what he is doing. But the trouble is that he does not know what he is doing, except in a few cases. The man who knows most about drugs is the man who uses them least; and the man who uses the largest number in one prescription is the man who has the smallest right to use any at all.

How Drugging Arose in the Days of Medical Ignorance

Drugging dates from days when nothing was known about the body, or about disease, or about drugs. That in itself ought to be reason enough for distrusting the practice as a whole; but a far more cogent reason than the ignorance of the past, which invented and practised drugging, is the knowledge of the present, which has studied the body and has ascertained the causes of most forms of disease. Voltaire was fully entitled to his celebrated remark about the doctor of his day—that he poured drugs of which he knew little into a body of which he knew less. The scientific study of drugs was not even conceived of in those days; there was nothing fit to call physiology; and as for disease, it was an utter mystery. Doctoring and drugging were therefore bound to be just as honest and useful as if we should now pretend to doctor bad weather, which we neither understand the causation of nor can control; and Molière was abundantly justified in his satire upon the charlatans of his time, and their windy, meaningless explanations of what no living man up to that time understood—as when he makes one of his medical characters declare that the properties of opium are due to it "vis dormitiva," which is merely Lati for "sleep-giving power."

Those were the days before Pasteur—and that means almost infinite things. The causes of disease were quite unknown. Thus here was to be seen an ill man wh suffered from pain and fever. In th absence of any knowledge of a caus underlying these symptoms—for that is a they are—the symptoms *were* the diseas The body was misbehaving itself in the for of pain and fever. To remove or smudg over these symptoms therefore ranked a curing the disease—until the patient die

The Confounding of the Relief of Symptoms with the Cure of Disease

But while these symptoms, wrongl and shallowly described as diseases, wer to be met in the sick-room, the fields an the woods provided certain plants th leaves or juice or roots of which coul also cause remarkable phenomena in on who swallowed them, and such drug could accordingly be pitted against th symptoms of disease in order to neutralis them, which was called curing the disease and which is even today the greater par of so-called medical practice. Thus th dried juice of the poppy capsule relieve pain and sleeplessness, which are amon the most distressing symptoms of illness though opium never cured anybody o anything yet; and the leaves of the fox glove would slow down an unduly rapi pulse, though foxglove, or digitalis, valuabl drug as it is, never yet cured a disease heart. These are typical and long-standin instances of vegetable therapeutics—th most ancient form of medical practice i the world, now reduced to the smalles proportions on record in the practice o the leaders of medicine.

The Absurd Assumptions that Underlay the Use of Vegetable Antidotes

When we come to think of it we see that there is no particular reason why th vegetable world should provide substance specially fitted to relieve the maladies of man. "To every natural evil the Author of Nature has kindly prepared an antidote" is not a doctrine which seems reasonabl to us today, as so stated. Our forefathers did believe that everything was made for man. Every living creature was supposed to be his minister. Thus the most reasonable expectation regarding herbs and plants was that they must be the antidotes provided for the ills that flesh is heir to. Further, it was observed that certain

plants had leaves which were of much the same shape as the kidney, or which had liver-coloured splashes upon them. This was the basis for the famous old doctrine of "signatures," according to which the kidney shape of the leaves was a sign, or signature, telling mankind that this particular plant would be useful for that particular organ—kidney or liver or whatever it might be. All this, no doubt, sounds incredibly ridiculous and absurd today, and we marvel that sensible people could believe such rubbish; but we do not allow for the primary assumptions of their philosophy, and we forget that we are doubtless crediting just such absurdities at which our posterity will marvel.

The Scientific Heresy that Herbs Exist for the Curing of Men

Now, once the doctrine that all herbs and so on were made for man has broken down, and the doctrine of "signatures" therewith, we see that the plant exists for itself, as we do for ourselves. It has its own life to live, its own enemies to outwit or repulse, its own kind to perpetuate. If a man has neuralgia or the heartache, that is really his affair. He has no more reason to expect help from the foxglove than the foxglove has reason to expect help from him in *its* little difficulties. Darwin showed long ago that each species exists for itself, and that there is no instance of any species being adapted in any way so as to serve the life of another. That fact strikes, we now see, at the very foundations of vegetable therapeutics. It does indeed so *happen* and "happen" is undoubtedly the right word here—that the foxglove contains a group of chemical bodies, of the class called glucosides, which have a special action upon the animal heart. Walking in the country once, the writer was challenged on this point, the argument being that every plant must similarly have been made to serve mankind. But a slightly larger dose of foxglove than will improve the heart's action will arrest it for ever; and so with the remarkable drug contained in the deadly nightshade, or with any other.

How Plants Strive to Repel their Own Enemies—Not Man's

There is no good reason, let alone any inherent necessity, why the active medicinal substances found in the vegetable world should serve ailing man. The facts and the probabilities are all the other way. Most of these medicinal substances, found in and made by plants, appear to be either poisonous by-products of the plant's own life, which it is in process of destroying, or else poisonous substances which it has produced to protect itself from the animal world. Those interpretations do not sound so hopeful as our ancestors' did, from the point of view of ailing man. Thus the delicious volatile oils which furnish the finest odours are probably produced by the plant in order to warn off objectionable insects, or to destroy them if they approach; and a nauseating leaf does not constitute a thoughtful vegetable anticipation of the occasional emetic needs of man, but a means of ensuring that the animal who seeks to make a meal off such a leaf shall studiously permit the tobacco plant, let us say, to grow in peace for the future.

In point of fact, the vegetable world has been ransacked, for ages, in all parts of the world, and everything, or nearly everything, has been tried for the cure of disease. Weighed and found wanting is the almost universal verdict. A mere modicum of drugs remain that have useful actions of one kind or another. Most of them are useful, not on account of anything they do to the human body, but because the very antiseptic substances which the plant uses to protect itself against microbes may be employed by man to protect him against similar microbes.

Quinine the One Vegetable Medicine that is Specifically Useful

And, in sum, there is only one human malady, or only one of any importance, for which the vegetable world provides a cure. It is just a chemical accident that the alkaloid called quinine, produced for its own purposes by a particular plant, arrests the chemical processes which serve the life of the animal parasite of malaria. This is a fair instance of the exception which proves the rule.

The fact is that the chemistry of the vegetable world exists for itself, and is irrelevant to our needs. The observant have guessed this all along; but it is a thousand-fold proved in our day, when we are learning to make the drugs, of a wholly new type, which do really meet the needs of disease. That helps us to see how absurdly irrelevant are the drugs in ordinary use. The chances that vegetable products will cure human diseases are almost nil—quinine is just the one exception. But certainly the chances are greater that particular functions of the body may be affected by vegetable products, and thus that many of the *symptoms* of disease may be modified. Thus morphine and strychnine and atropine are often of great use in medicine, though there

is no form of disease which any of them cures. The discovery of the real causes of disease, mostly in the form of minute vegetable parasites, has at the same time displaced the vegetable kingdom from the proud place which it has hitherto held in the pharmacopeias of barbaric and civilised peoples alike. Vegetable drugs still outnumber all others many times over in the list of materia medica, but hundreds of them might be permanently forgotten without anyone ever being a whit the worse, whatever his plight.

It is a great pity that the accredited teachers of medical students on these subjects are so slow in letting go all the burden of useless materials which modern medicine inherits from the past. The examination system is largely to blame; but the time must soon come when these teachers will initiate a great reform in medical practice, and will encourage their students in as intelligent a contempt for the vast majority of drugs as they entertain themselves. At present, these teachers, with very few exceptions, consider it necessary to allude to practically every drug contained in the pharmacopeia of the country in which they teach. But they know perfectly well, none so well, that far more than half of these are mere survivals from the pre-scientific age, the very existence and accessibility of which promotes unscientific and meddlesome and frequently deadly medical practice. There needs drastic revision of the common medical curriculum in this respect.

The Proved Inefficacy of Vaunted Vegetable Remedies Like Sarsaparilla

Two very remarkable instances of the trend of modern therapeutics may be quoted. One of the most terrible of all diseases, still only too common, is best treated, as a rule, with mercury. But at one time mercury fell into disrepute, having been used very injudiciously and carelessly; and for a considerable period this terrible malady, syphilis, was regularly treated with a vegetable drug called sarsaparilla. Of course, no doctor nowadays treats syphilis with sarsaparilla, but observe. This drug has been exhaustively tested by the delicate and accurate methods of modern science, and the most careful and prolonged experiment has failed to show that it is capable of exerting any kind of influence upon any function or organ of the animal or human body, in health or disease, or upon any known form of disease parasite. In short, we now know that syphilis treated with sarsaparilla was untreated—and the consequences were hideous.

A second instance is very slight, but it is typical of very many more. "Tincture of arnica" long held, and even now enjoys, a great reputation as a specific in the treatment of bruises. But the matter has been tested; and we now know that, if the arnica be omitted from the tincture, the mechanical action of the alcohol, and the rubbing associated with the application of the tincture, completely achieve the good results with which the arnica was formerly credited, and, in point of fact, arnica is as inert as sarsaparilla. But they are both in the pharmacopeia still; and students of pharmacy and medicine are at this moment busily engaged in learning what they are, how to prepare them, and in what doses to administer them.

The Millions Killed for One Cured by Vegetable Drugs

The chances of any future discoveries of any moment in the vegetable world for the treatment of disease are exceedingly remote. It is, of course, always conceivable that something might turn up which was as useful, say, in leprosy or pneumonia as quinine is in malaria, but that is the utmost we can say; and modern researchers, all the world over, are now engaged in infinitely more profitable and promising directions. On the whole, if we exclude the unique exception of quinine—which might very well have changed the whole face of history if the ancients had possessed it—it is safe to say that for every patient whom a vegetable drug has cured, throughout the whole history of medicine, millions have been killed; and this doubtless remains true even if we leave out of account the awful history of the unholy alliance between alcohol and medicine in the past, now in process of rapid dissolution.

The Lost Reputation of Mineral Medicines When Tested by Experiment

In the mineral world we find a parallel state of things. Iron, arsenic, mercury, sulphur, to choose notable examples, certainly have their uses, and doubtless always will have. Iron in certain forms of anæmia, mercury in syphilis, sulphur in many parasitic diseases of the skin, are not to be denied the title of cures. But on the whole the drugs derived from the mineral kingdom are in a state of decadence in modern scientific medicine. An excellent illustration of this truth is furnished by the celebrated drug called antimony, with its various medicinal preparations, which were popular for so long, and must have done hundreds of thousands of unfortunates to death. Like all other drugs whatsoever, antimony has had to face the tests of modern science, and it has been

found wanting. It depresses the essential functions of the body, beginning with the heart, and is probably worse than worthless in all conditions of disease.

A definite name has been given to the new science which has changed the face of medical practice in such respects, and which has given us such a humble opinion of so many drugs once trusted. It is this science whose verdicts underlie the argument of the present chapter that popular self-drugging is directly against the teaching of modern research.

Its name is pharmacology, and its province is the action of all imaginable drugs upon the *healthy* body of man, and of animals (for there is all the need of veterinary medicine to meet as well), and even of plants. A century ago, and much less, there was no such thing as pharmacology. The action of drugs was only inferred from what appeared to happen in disease. Practically nothing could be so learnt, and most of the positive conclusions reached under such hopeless conditions were wrong. Thus, the great heart-stimulant foxglove, or digitalis, was introduced and used for many years as a heart-sedative, because it slowed the pulse in the supposed over-action of fever. All this was wrong. The heart in fever is not over-acting, but it is poisoned, and is beating too fast because it cannot beat strongly enough; and the action of digitalis is to strengthen the beats, and therefore reduce the rate of beating that was formerly necessary. Similarly, it is pharmacology that has condemned sarsaparilla and arnica as inert, and antimony as poisonous, and it is recent pharmacology, especially within the last fifteen years, that has reversed all the popular and professional opinions about alcohol, as we shall see, proving that the supposed stimulant is a sedative, just as it proved that the supposed sedative digitalis is a stimulant.

On the whole, the result of this new science has been to discredit the overwhelming majority of all the drugs used in the past, and to reduce the number of them that are still worthy of use to a mere handful. These negative results of modern knowledge have been especially insisted upon in this introductory chapter; but the reader is by no means to suppose, because the old "shot-gun" prescription of the past is condemned, together with the great majority of the drugs upon which the student still spends so much time—that therefore the chemists and the students of the actions of drugs have made themselves superfluous. On the contrary, they have in reality been preparing the way and clearing the ground for a new era. We have argued that the chemistry of the vegetables can scarcely be expected, except on the view that all things were specially created for the service of man, to fit the particular needs of his body in illness; and the same argument applied to substances of mineral origin. These very moderate expectations were justified by the experiment and observation which have reduced to a bare few the drugs, of such origin, that are employed by the leading modern physicians, and which have furnished signal condemnation of the habit of giving or taking drugs promiscuously and persistently.

A TWELFTH CENTURY DISPENSARY
Reproduced from an old manuscript at Trinity College, Cambridge

But the reader will observe that, besides the vegetable and mineral kingdoms, there is a third, to which we have not even alluded as yet. Might not the animal kingdom furnish chemical resources well suited to serve the needs of such another animal as the body of man? Here is quite a new idea—only that it is also one of the oldest in the history of the medical art. The answer to this question must engage our next chapter, and will engage the attention of medical science for many decades to come. At the present moment there is scarcely a worker on these subjects throughout the civilised world who is not engaged upon exploration in the animal kingdom for means to cure disease; and the reason for this remarkable concentration of their attention will be evident in the sequel.

IN TOUCH WITH THE BRITISH FLEET

It is said that, after much delay, Admiral Sir John Fisher finally used his bluejackets to rig up in Whitehall the wireless installation whereby the Admiralty hears daily from all the fleet.

THE WIRELESS TELEGRAPH

Bridging the Atlantic Ocean with a Current of Electric Waves Each Five Miles in Length

THE INVENTION OF A LAD OF TWENTY-ONE

On a cold, foggy winter day, a few years ago, three young men were apparently playing at kite-flying on the sea cliffs of Newfoundland. Close to them was an old signalman, who stood looking out to sea, and watching for ships. He was much amused to see three young men taking the childish game of kite-flying so seriously. One of their toys was a huge thing of bamboo and silk, nine feet high, with a wire attached. But when it was well flown, the wind snapped the wire and blew the kite out to sea. A balloon was then sent up. That also broke away and vanished into the fog.

The three young men grew very anxious. But they still kept on with their kite-flying, and the next day they managed to get a kite four hundred feet up in the windy sky. They fixed the wire from it to a pole by the old signal-house, and then connected the wire to the curious-looking instrument on the table. The instrument ended in a special telephone receiver; and at 11.30 o'clock on the morning of December 12, 1901, one of the young fellows, thin and resolute of face, with blue and strangely bright eyes, sat down at the table, and put the telephone receiver to his ear. For a long time not a sound broke the stillness of the little room, save the wash of the waves three hundred feet below Signal Hill. The eyes of the three young men were fixed on the clock.

"You try, Kemp," said Marconi.

The Englishman went to the table and put the telephone receiver to his ear. At ten minutes past one he heard three clicks, as sharp and distinct as the rap of a pencil on the table. Two thousand miles away, at Poldhu, in Cornwall, one of Marconi's assistants was making three quick taps with the key of a new kind of telegraph apparatus. Every time he pressed the key a fierce current of electricity leapt across a gap in the wire and made a blue spark of lightning. At each spark, the electric energy surged wildly to and fro between the spark gaps, somewhat like a vessel of water that had been strongly disturbed. Waves were formed in it; and these waves of electro-magnetic energy surged up and overflowed, and broke away from the apparatus and went rippling through the air.

For a height of thirty-five miles between the surface of the sea and the thin upper atmosphere, there is a mass of dense air which is often a very bad conductor of electricity. And just because it was a very bad conductor, Marconi was now using it as a new kind of telegraph wire. Marconi was not fully aware of the fact himself. He was inclined to think at the time that the waves of electricity made by his machine penetrated through every form of matter, and were independent of any material medium. But the real truth was he was using a mass of air about thirty-five miles high, and two thousand miles long, instead of a copper wire.

Through this new and wonderful kind of telegraph line, stretching from Europe to America, the waves from the three trains of electric sparks kept rippling. They stood for the three dots of the Morse code representing the letter "s." Reaching the wire on the high-flying kite, they ran down the pole, and passed through the window, and entered the instrument that Marconi had placed on the table. Very feeble were the waves, after forcing their way through two thousand miles of resisting air at a speed of 180,000 miles a second. No matter by what powerful instruments for magnifying sound the human ear was assisted, the presence of the dying waves of electro-magnetic force could not be detected. The current in ordinary wire telegraph must last

for $\frac{1}{500}$ of a second in order to affect a detecting instrument. In wireless systems, on the other hand, the currents only last $\frac{1}{100000}$ of a second. To detect them in that extraordinarily short space of time requires a marvellously sensitive electric mechanism.

But Marconi had long known this, and he was prepared with an instrument responsive to influences far beyond the powers of human sense. It consisted of a current of electricity produced by a battery on the table in the room of the signal-house. It was this local current that made the three taps in the telephone receiver; but it was only able to produce these sounds when the faint electric waves came down from the wire on the kite, and affected a wonderful piece of mechanism connected with the battery. The instruments used by Marconi in the signal-house in Newfoundland would make a young wireless operator of the present day smile. They were very primitive, and the transmitting apparatus in Cornwall was also crude and defective. This is why the experiment which has now changed the world seemed at first to show that the young inventor and his two assistants had been flying kites on Newfoundland to no purpose.

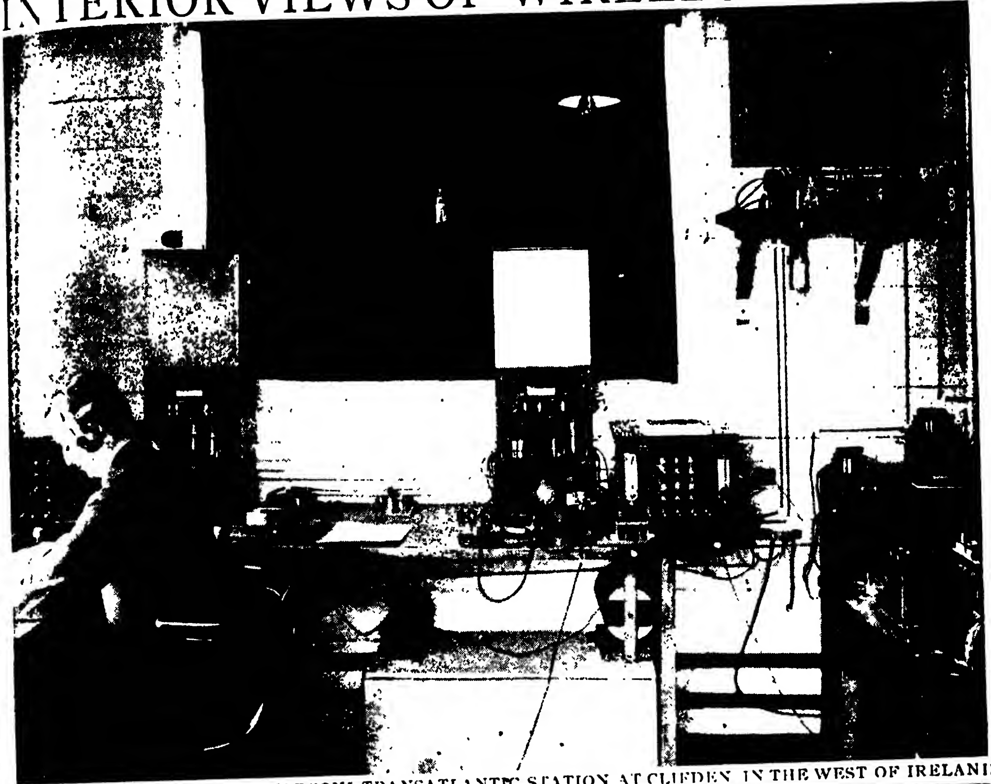
GUGLIELMO MARCONI

For though the operator in Cornwall was, in accordance with his orders, flooding the Atlantic Ocean with the electric messages, it was a long time before the electric waves had any effect on the local current in the signal-house. Though Marconi did not know it, he was engaged in a battle against the terrific forces of the sun. His telegraph line of two thousand miles of air was being bombarded by electric rays from the tremendous furnace in the heavens. The sun was, in fact, electrifying the air and making it absorb. instead of transmit, the waves of force sent out by the insignificant spark from the little machine on the coast of Cornwall. Had Marconi waited till midnight, his telephone receiver might have rattled away for hours with the br-br-br of the electric waves.

But thanks to the fog and clouds and biting cold of the Newfoundland winter, the air of the Atlantic Ocean was only imperfectly electrified by the sagging and oblique sun. The result was that now and then the three longed-for taps resounded in the magnifying microphone of the telephone receiver. Enough had been discovered to make the task of the old signalman, looking for ships and laughing at the kite-flyers, a figure of the past. No human eyes were now needed to watch for ships plying between Europe and America. Even the sword of light with which the great lighthouses pierced the darkness, and the hoarse, long cry of warning that they sent through the fog, were now no longer needed. Mankind had at last really chained down the lightning, and transformed the electric flame into a voice that could link ship to ship, when hundreds of miles apart, and cover the largest and stormiest ocean within visible guiding lines, connecting every vessel with the land behind it and the land before it.

The curious thing about wireless telegraphy is that all the experimenters began with a wrong idea. Marconi himself set out to use the mysterious ether for the transmission of electric waves and it was not until 1902 that he found he was really employing earth or air as a telegraph line. It took him nearly six years of continual and difficult experiment to make the atmosphere of the Atlantic Ocean into a reliable supermarine cable. His instruments had to be constructed in a new way, and his transmitting and receiving stations had

INTERIOR VIEWS OF WIRELESS PLANTS



OPERATING-ROOM OF THE MARCONI TRANSATLANTIC STATION AT CLIFDEN IN THE WEST OF IRELAND

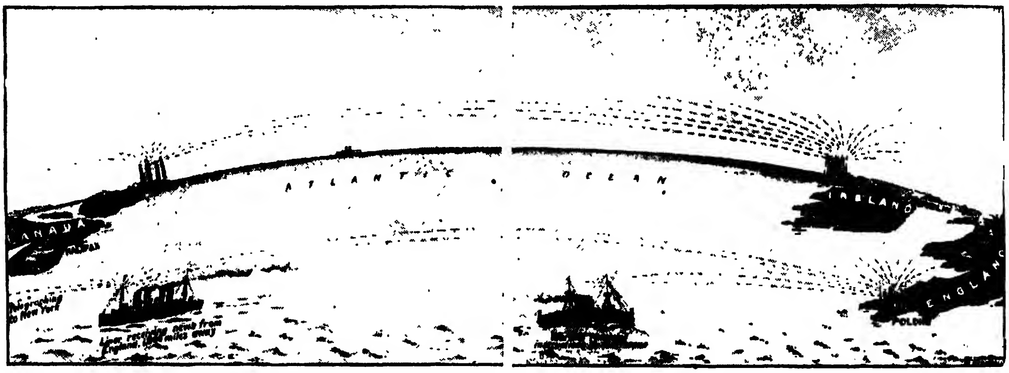
OPERATING-ROOM ON THE "BALTIC," ONE OF THE SHIPS WITHIN CALL OF THE "TITANIC

also to be built in an entirely different manner. Only by an extraordinary fertility of inventive genius were all the difficulties surmounted, but at last in 1907 a public service of wireless telegraphy was working successfully between Ireland and Canada. So wonderfully efficient were the new instruments that messages were received at a station in South America seven thousand miles away from the dispatching point in the British Isles—that is to say, nearly five thousand miles more than the distance for which the service was designed. And now a station is being built at Coltano, in Italy, which is expected to have a radius of transmission of ten thousand miles.

But when Marconi began experimenting with electric waves, he had very great trouble in telegraphing without wires over two miles. He was then about twenty years of age, and he had been studying electricity at the University of Bologna, under a very able man of science, Professor Righi. Righi was then busy developing the ideas of Heinrich Hertz, who at the age of thirty had discovered the actual existence of small electric waves. It had been long known that such waves existed. Faraday had worked out the theory of them, and Clerk-Maxwell, of the Cavendish Laboratory, Cambridge, had developed this theory, and made it the fundamental principle of the science of electro-magnetism and light and heat. At that time the existence of the waves had to be taken for granted, and it was not until 1879 that a means of detecting them was discovered. This was accomplished in extraordinary circumstances by Professor D. E. Hughes, the famous London man of science, who perfected the modern telephone.

It was Hughes who invented the speaking part of the telephone, that changed it from a scientific toy into a force in civilisation. It was a disinterested invention, in which Hughes refrained from keeping any patent rights. The instrument consisted of a number of little carbon grains which blocked the passage of an electric current that was produced by a small battery. These grains, however, could be made to come together when the telephone was used in speaking; as electricians put it, the grains "cohered," and allowed the electrical current to pass through. Such was the practical value of the microphone—as Hughes called his curious instrument, which in an improved form is now built into the mouthpiece of the modern telephone. Out of curiosity, however, the London inventor tried to find out if his microphone could detect the mysterious electric waves sent from a distance. It did. For the grains of carbon cohered when a train of electric waves affected them. So Hughes continued his experiments, and, after working out a rough idea of wireless telegraphy, he brought the matter before Stokes, the President of our Royal Society and Professor Huxley. Sir George Stokes refused to believe that a human being had been able to detect the presence of mysterious waves of electro-magnetic force in the still more mysterious medium of the ether. He reckoned that Hughes was misled by some trick of his instrument, and under his advice the inventor refrained from publishing his discovery. And Hughes was so discouraged that he entirely discontinued his marvellous experiments.

We have no right to suppose that the discouragement of science under which Roger Bacon laboured in the thirteenth century is a mediæval mistake which we



PICTURE-DIAGRAM SHOWING HOW WIRELESS TELEGRAPHY BRIDGES THE ATLANTIC

have long since learned to avoid. It was Stokes, one of the leaders of British experimental knowledge, who quashed Hughes more effectually than the Inquisition quashed Galileo. Still more recently Haeckel, the most famous of living German men of science, has fiercely and bitterly attacked a younger man for making a very important discovery about the conditions of life in the sea. Happily the man that Haeckel has tried to discredit and discourage has more of the fighting instinct than Professor Hughes. It is Haeckel who is now discredited and silenced in regard to the matter.

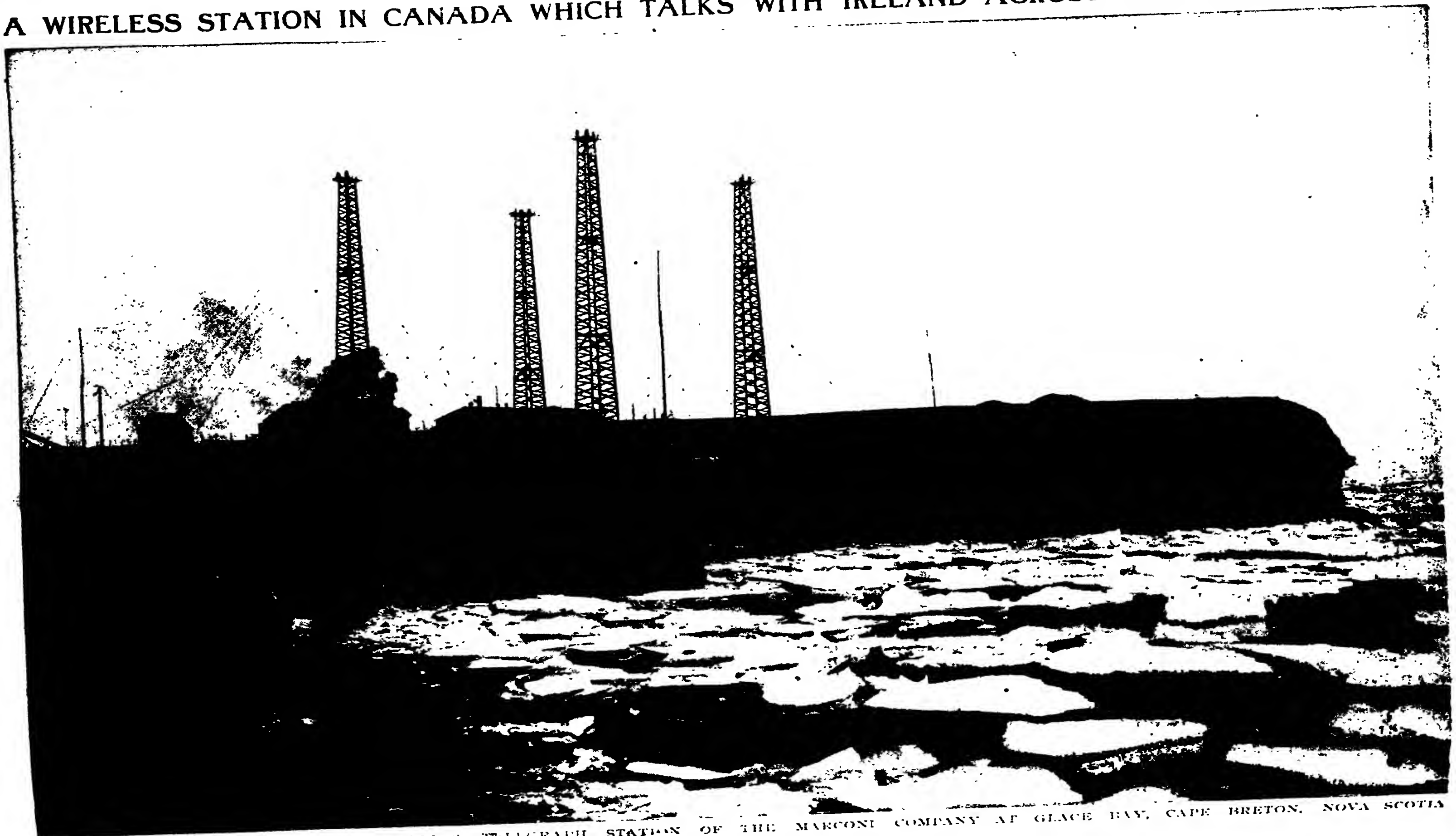
But Hughes was a sweet and gentle fellow, and he was unable to withstand the force of authority that was brought against him by the scientific committee, led by Stokes and Huxley. He was able to show by actual experiment in 1879 that wireless telegraphy with electric waves was possible. He used a machine for making electric sparks that set up a train of ripples in the ether. These ripples of electro-magnetic force went through walls and houses, for they were not conducted through the air or the earth. They were movements in the fundamental substance of the universe—the impalpable, all-pervading ether that fills the emptiness between star and star, and between sun and planets, and underlies and penetrates everything that we call matter.

THE MONSTER CONDENSER PLATES AT CLIFDEN

It is through the ether that the light from a star, a billion miles away, travels to us. Light consists of very small electric waves, and we have natural organs of ethereal sense—our eyes—which detect some of these. Our ears can discern only material waves of air; they could not find anything existing in the empty spaces between world and world. But our eyes can record waves of electric energy of microscopic size. It is only when these electric waves exceed the power of our vision and the power of our sense of heat that we have to make instruments to detect them. Hughes's microphone was an instrument of this sort. It could detect electric waves some inches in length. It was the first coherer; and Marconi used an improved form of it when he took up the study of waves of electrical energy, though now magnetic detectors and platinum wires and microscopic crystals of lead are employed in various wireless systems. Hughes himself was conducting wireless experiments over several hundred yards when he was told by a committee of leading Englishmen of science that he was merely dreaming an impossible dream. But nine years afterwards, Heinrich Hertz, a young professor of physics, who had studied under Helmholtz, rediscovered the electric wave. He also used an electric spark that sent out ripples of energy, but his detecting instrument was very crude. It consisted merely of a broken ring of metal, with two small knobs at the broken ends. The presence of the waves was indicated, some distance away from the sparking-machine, by the reproduction of very small sparks between the knobs of the ring. Hertz was able to study the properties of small electric waves, but his instruments were much too imperfect for any practical kind of wireless telegraphy.

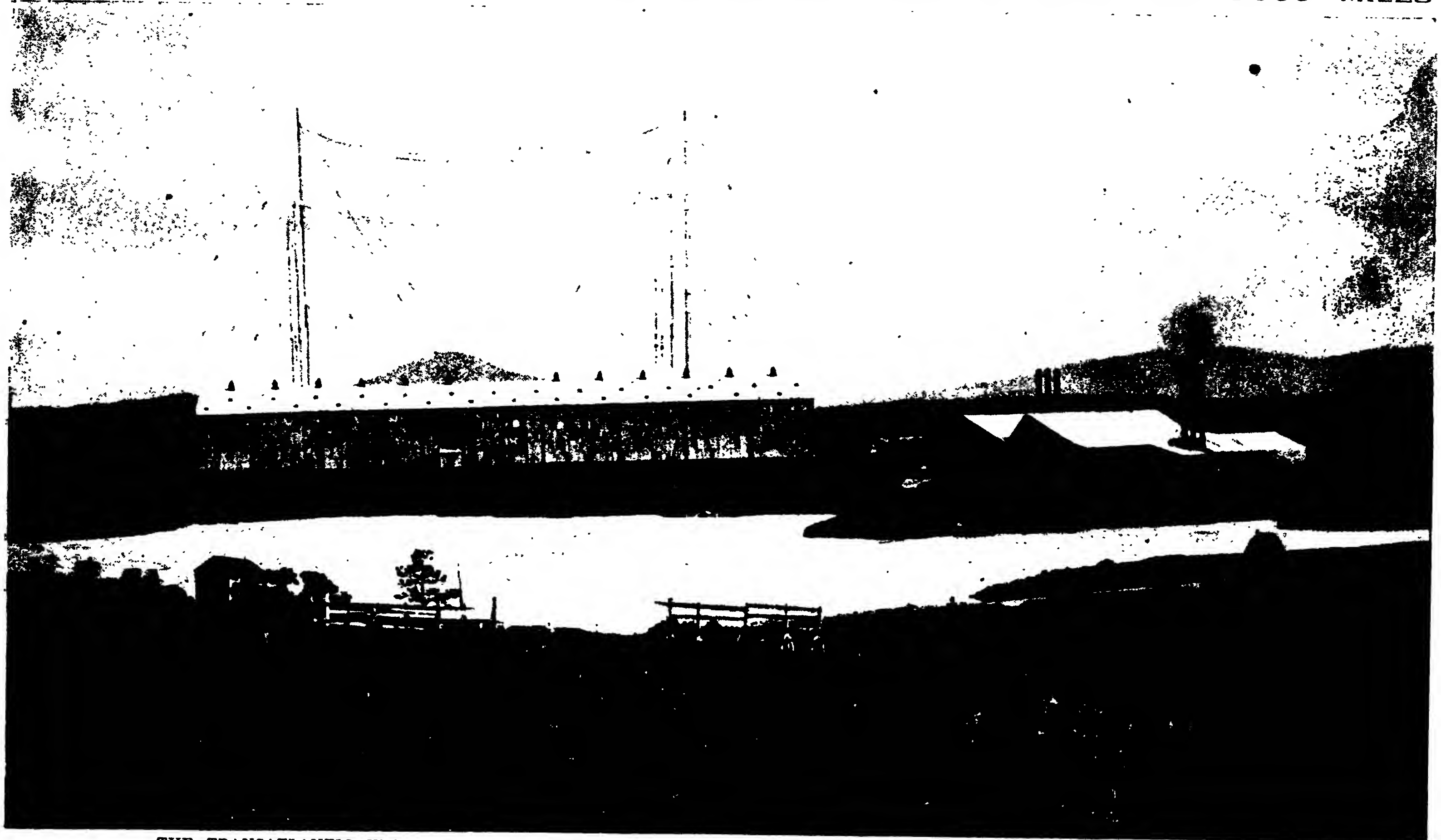
It was not until Professor Branly, of Paris, invented a coherer, somewhat like Hughes's, that the electric wave became likely to be of practical importance. Then Professor Righi, under whom Marconi was studying, designed a new apparatus for producing an electric spark, and a primitive kind of wireless telegraphy at once became again possible. The ground lost in 1879 was now regained—abroad! In 1894, Guglielmo Marconi, a university student twenty years of age, began to think of

A WIRELESS STATION IN CANADA WHICH TALKS WITH IRELAND ACROSS 2000 MILES OF SEA



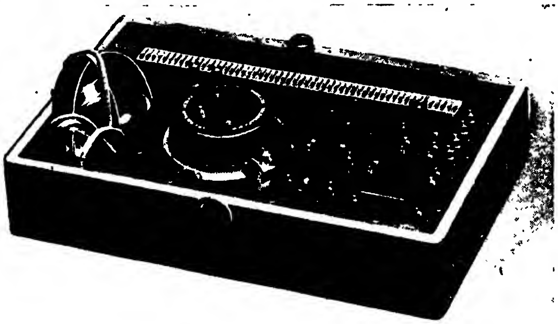
THE POWERFUL TRANSATLANTIC WIRELESS TELEGRAPH STATION OF THE MARCONI COMPANY AT GLACE BAY, CAPE BRETON, NOVA SCOTIA

A STATION FROM WHICH WIRELESS MESSAGES CAN BE SENT FOR 7000 MILES



THE TRANSATLANTIC WIRELESS TELEGRAPH STATION OF THE MARCONI COMPANY AT CLIFDEN, GALWAY, IRELAND

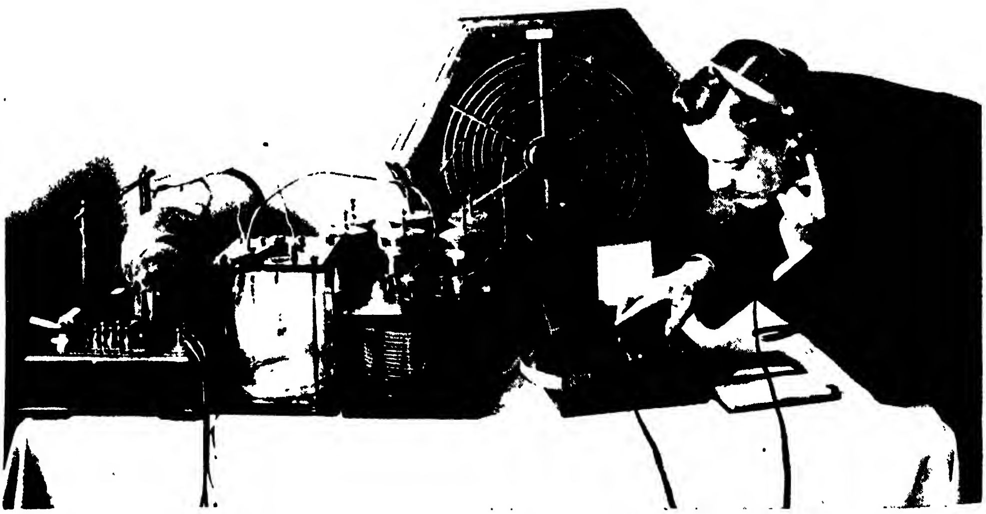
sparking a message across the world without any wires. At first he did not take the trouble of making experiments, as he felt sure that all the leading men in electric science were attacking the problem with more knowledge than he possessed. A year passed, however, and there was no sign of any general interest in the practical side of the new discovery. So Marconi took the electric waves of Hertz, the coherer of Branly, and the sparking machine of Righi, and tried to build these three things into a new kind of wireless telegraphy. He was in the fortunate position of being well instructed in electrical science, and his father was a rich man with a large estate near Bologna. His mother, by the way, was an Irishwoman, and from her Marconi gets his blue eyes, fair skin, and English speech that make him seem a typical Britisher rather than a son of Italy.



THE DECREMETER THAT FINDS WAVE-LENGTHS

through the ether, making a series of circles, such as would be made in water by dropping little stones in the middle of a pond. The circles of ripples spread out until just a fragment of their edge passed through the tin box at the end of the garden. In the tin box was a glass tube that acted in the same way as Hughes's microphone. It contained some metal filings that usually prevented the current from the battery from passing through the tube.

When, however, the electric waves reached the filings, it made them cohere. So the electric current passed through, and then did whatever work the inventor desired made a click, or left a sign on paper. In order to make the instrument practical, it was necessary to use the current also to restore the metal filings to their loose arrangement, so that they could be acted on by the next electric wave.



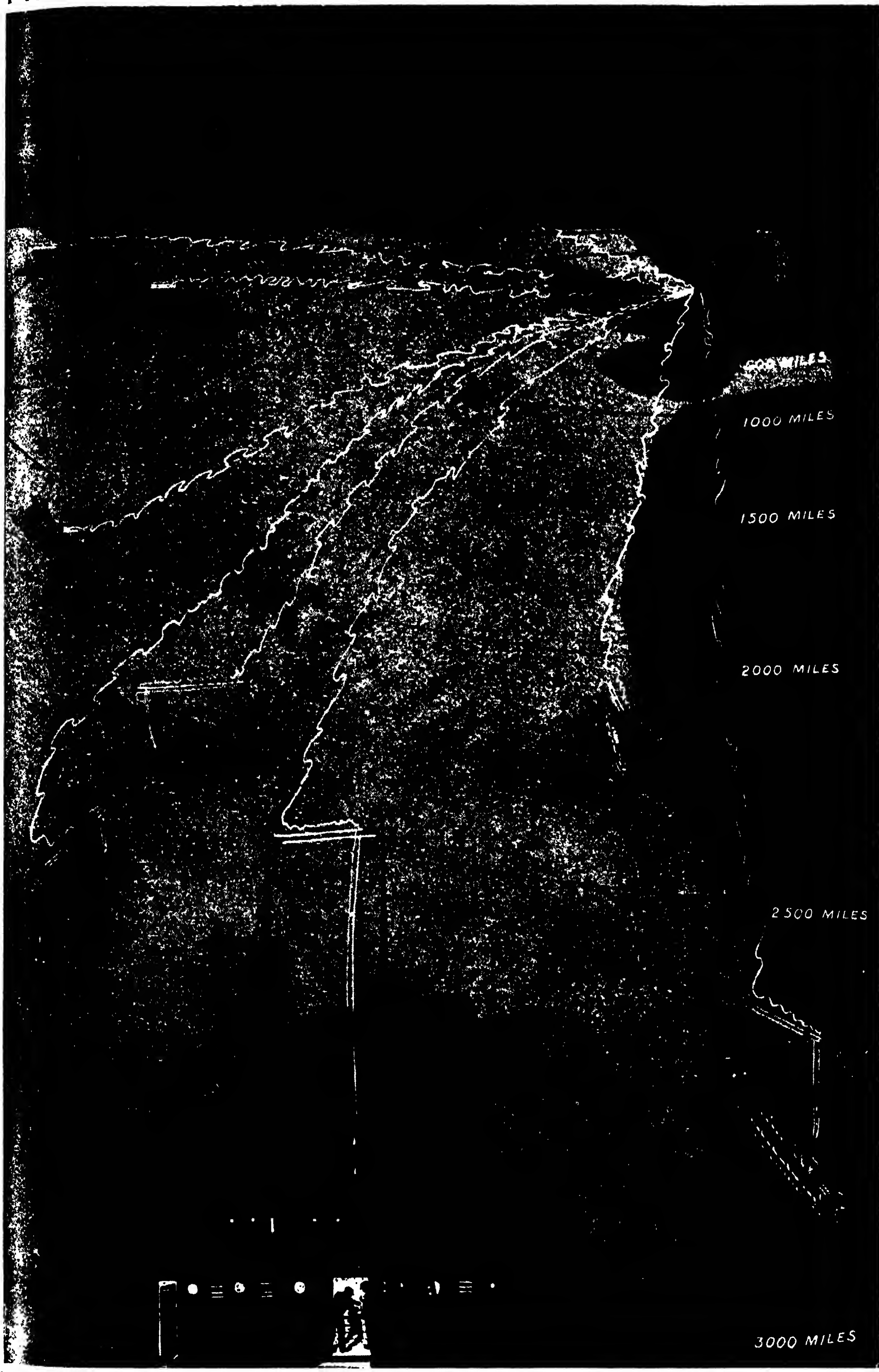
REVOLVING THE DECREMETER SO AS TO GET ONE INSTRUMENT INTO TUNE WITH ANOTHER

In his experiments Marconi put two tin boxes on the top of two poles, set at some distance from each other in his father's garden. One of the boxes was connected to a sparking instrument which could be worked by means of an ordinary telegraph key. The waves spread from the tin box

This was first done by a tapper, invented by Sir Oliver Lodge, that struck the tube, and jarred the filings apart.

While Marconi was developing his instrument on his father's farm, two or three other men were experimenting with electric waves. The most successful seems to have

TIMING MIDNIGHT FIVE THOUSAND MILES



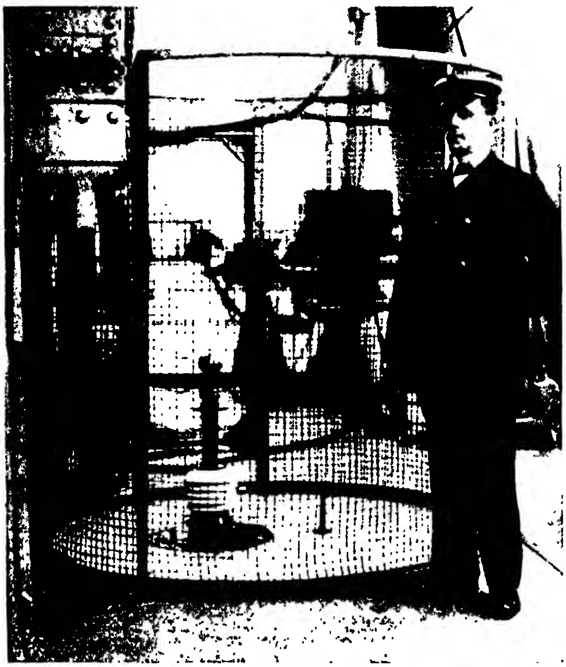
The Eiffel Tower, now used for wireless telegraphy, announces the exact moment of midnight over a circle five thousand miles in diameter, and thereby helps ships to take their exact bearings.

been Captain H. B. Jackson, R.N.—now Admiral Sir Henry B. Jackson—who, in 1895, anticipated the Italian inventor by actually succeeding in transmitting messages in the Morse code between two British warships by means of an apparatus very similar to that on which Marconi was working. Captain Jackson's system of wireless telegraphy was, however, kept a naval secret. It was the property of the Admiralty, and no details were revealed.

So the field was left open to the young Italian inventor, who arrived in England in February, 1896, with a method of sending messages by electric waves over a distance of two miles. The waves went through walls and even houses, so it was clear that they were pure ripples in the ether that sped on their way, without any help from material objects. At this stage, Marconi's system was a veritable ethereal system. He used the same short kind of waves that Hertz had used; and these short waves rippled out in circles, forming a manifestation of electrical energy quite different in its action from an electric current. An ordinary electric current is also a movement in the ether, but, instead of this movement being independent of ordinary matter, it flows along some conducting wire. Copper is a thing through which electric energy can pass very easily; and when a copper wire is surrounded by some substance that resists the electric flow, the copper becomes a kind of pipe, so to speak, along which the electricity can be conveyed without much loss for hundreds of miles.

Now, the electric waves with which Marconi had been first experimenting were free electric waves. They started from the sparking-machine, and spread out in larger and larger circles, just as ripples in a pond do when a stone is thrown in the water. The trouble with these free electric waves, however, is that they quickly become feeble, and nobody has yet succeeded in detecting their presence at a distance of more than two miles from the point at which they were created. So Marconi was face to face with an enormous difficulty when he came to England and began to develop his system into something that would bridge the Atlantic, and throw a message ten thousand miles through space.

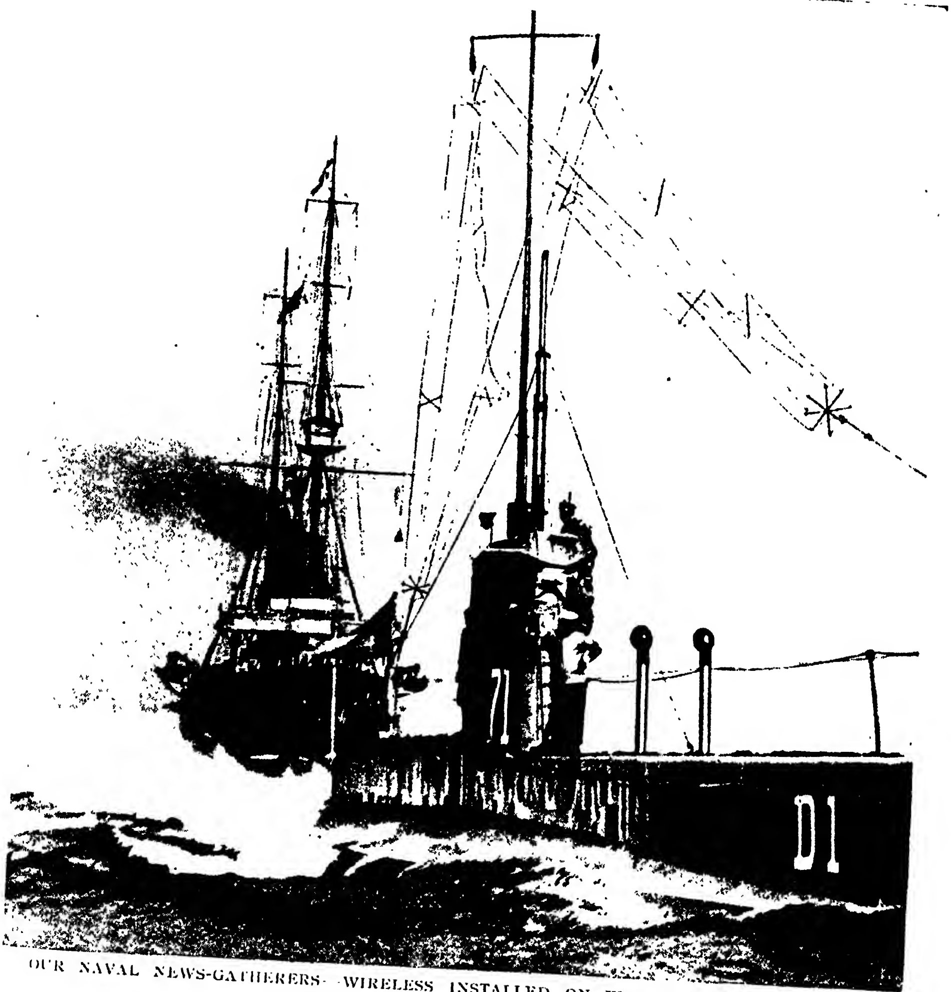
Perhaps it was well that the daring inventor of twenty-two years of age was ignorant of the task on which he was entering. He had so much faith in his small, free electric waves that careered where they would through the ether that he continued to trust in them when, as a matter of fact, he was laboriously working out a still more extraordinary system of communication. All that he directly aimed at was to increase the transmitting and receiving power of his machines. He went simply by the method of trial and error, using first this thing and then that thing, until he obtained some striking result. Of course all his theories were backed by a large fund of scientific knowledge. He also had an uncommon amount of ingenuity in devising new mechanical arrangements, and he was well acquainted with the practical details of ordinary telegraphy. In the ordinary telegraph, one of the wires is earthed, and the current passes down this wire, and through the earth, to the earth connection at the receiving station. The wire only serves as a path for the return journey of the electric current.



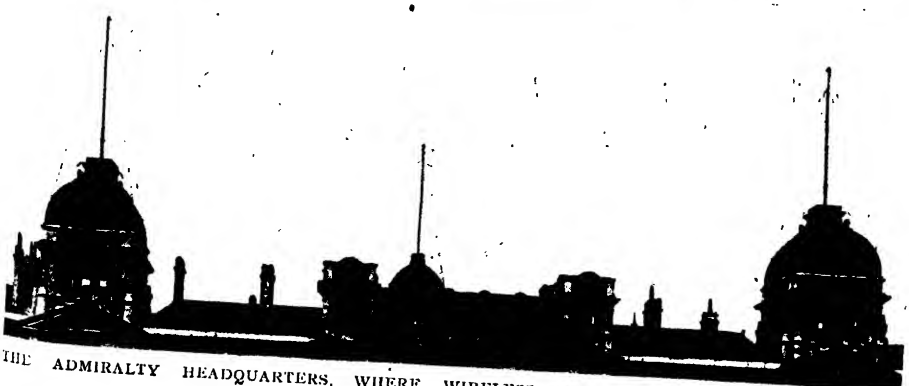
THE CAGE ON A WARSHIP WITHIN WHICH THE LIVE WIRES PASS DOWN INTO THE OPERATING ROOM

This point has only been made clear of late. It used to be thought that an electric current went over the wire and came back through the earth. Marconi upset this idea—without knowing that he

HOW WHITEHALL LISTENS TO THE NAVY

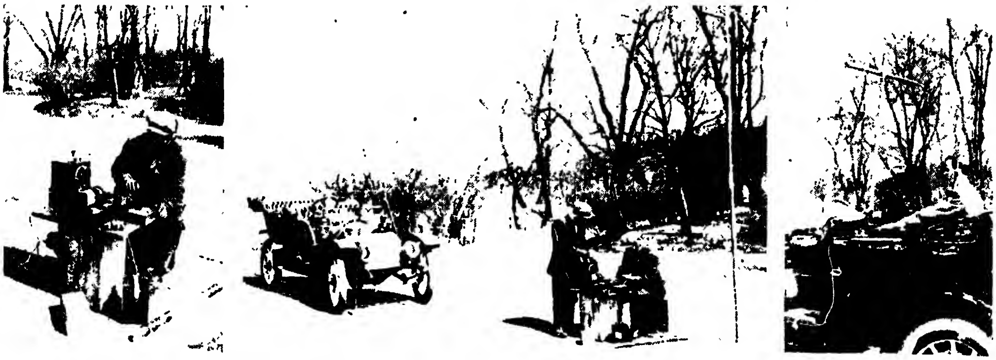


OUR NAVAL NEWS-GATHERERS: WIRELESS INSTALLED ON FLAGSHIP AND SUBMARINE



THE ADMIRALTY HEADQUARTERS, WHERE WIRELESS MESSAGES ARE BEING RECEIVED CONSTANTLY FROM THE FLEET

was upsetting it—by connecting his small wire to the earth, and fixing the upper part of it to a high pole. By this means he was able to send intelligible messages to eight or ten times the distance at which they could be dispatched by free electric waves. Of course, the practical value of this vast improvement was at once appreciated, For thirty-five miles above the surface of our globe the air is dense, and it forms a very bad conductor of electricity. Sending a current through it is somewhat like forcing a stream of water through, let us say, soft clay. Of course it is not quite so bad as that, but it is a fact that the air we breathe is much more resistant to electricity than



A WIRELESS INSTALLATION THAT CAN BE CARRIED ON A PRIVATE MOTOR-CAR
By the aid of portable apparatus the owner of a motor-car can keep in touch with home or business. The two pictures on the left show how messages are sent, and that on the right how a message can be received on the car itself.

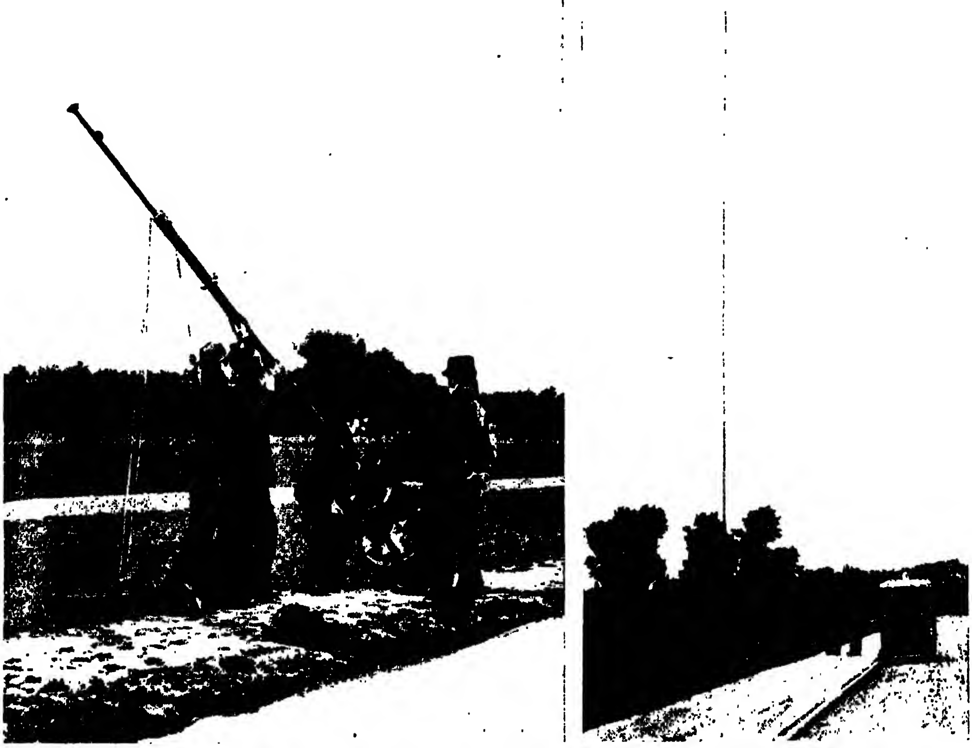
but the complete change which had been effected in the method of transmission was very slowly understood. The glamour of Hertz's discoveries of free electric waves blinded most men of science to the quite obvious fact that Marconi was using the earth as his telegraph line. And Marconi was in the strange position of getting the earth, and very much more resistant than sea water. Marconi overcame the resistance by constructing sparking-machines that sent out enormously long ripples of electric force. While the electric wave of light to which our eyes respond is only about $\frac{1}{50000}$ of an inch in length, the electric waves composing the currents from a modern

AN EXPRESS TRAIN FITTED UP FOR SENDING AND RECEIVING WIRELESS MESSAGES
A wireless installation on an express train may prove of value in the vast spaces of America. These pictures show an experimental wire fitted on a train running from Buffalo to Chicago, messages being sent and received in the train, as shown in the right-hand picture.

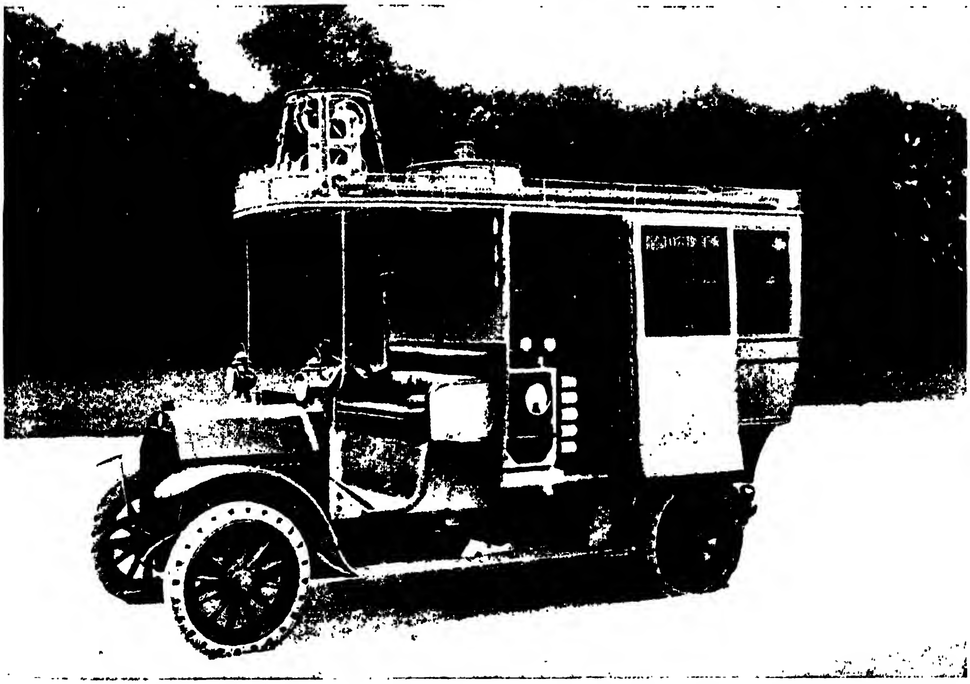
splendid results out of a wrong theory. Naturally he met with some strange difficulties. But each new trouble only stimulated him to further efforts. He continued to improve the power and the design of his instruments ; and, still without knowing it, he lifted his electric currents out of the earth and sent them through the air. wireless telegraph station are sometimes five miles long !

These huge waves force their way through the air, which then acts as an insulator, preventing the electricity from being dissipated either by the sea or by the conductive layers of atmosphere existing above the dense and resistant air. Such at least, is the

AN AUTOMOBILE WIRELESS STATION



THE ERECTION OF THE TELESCOPIC MAST FOR SENDING AND RECEIVING MESSAGES

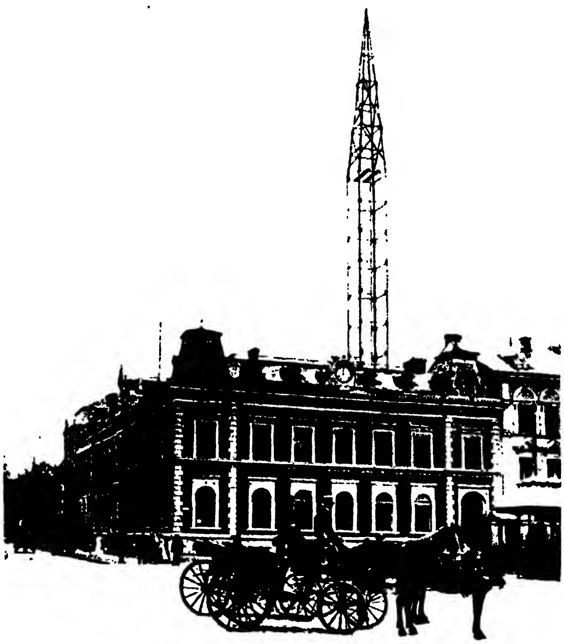


A CAR OF 22 HORSE-POWER THAT CARRIES A COMPLETE WIRELESS INSTALLATION

The French army has experimented, as shown above, with an automobile wireless equipment, which can be brought into operation in six minutes, and sends and receives messages over a radius of ninety miles.

theory based on Sir J. J. Thomson's experiments, which showed that when the air is electrified by sunlight and made more conductive, the electric current from a wireless station only travels half the distance it usually does at night-time. Mr. Marconi, however, is now inclined to think that the surface of the sea and the upper layer of the earth are of more importance in wireless telegraphy than the air. However this may be, it is certain that there is another factor of great importance in wireless telegraphy. When a ship, possessing instruments for producing waves about three hundred to six hundred yards long, is say, a thousand miles south of the British Isles, it can easily get into communication with the stations on our coast. But if the same ship is at a similar distance on the Atlantic in a westward direction, it cannot communicate with our shore stations.

There is a mysterious something stretching from north to south over our globe. It favours the course of a wireless electric current sent from north to south or from south to north. But this mysterious something shortens the range of currents sent eastward or westward. So greater power has to be used in transmitting messages in an east-westerly direction. Perhaps there is a constant stream of electro-magnetism flowing across the earth that dissipates the currents from some wireless stations, and assists communications from other places. Mr. Marconi is now busy studying the problem with new instruments which are extraordinarily sensitive. It has already been found, by using waves of the enormous length of some miles in Transatlantic experiments, that the amount of energy received in the day-time, when the air is electrified, is greater than that received at night, when the atmosphere is especially favourable to wireless messages. Yet in 1902, when shorter waves were used, the effect of daylight on long-distance messages was disastrous. They carried only half the distance that they did at night-time.



AN AERIAL ON A POST-OFFICE, SWINEMUNDE, PRUSSIA

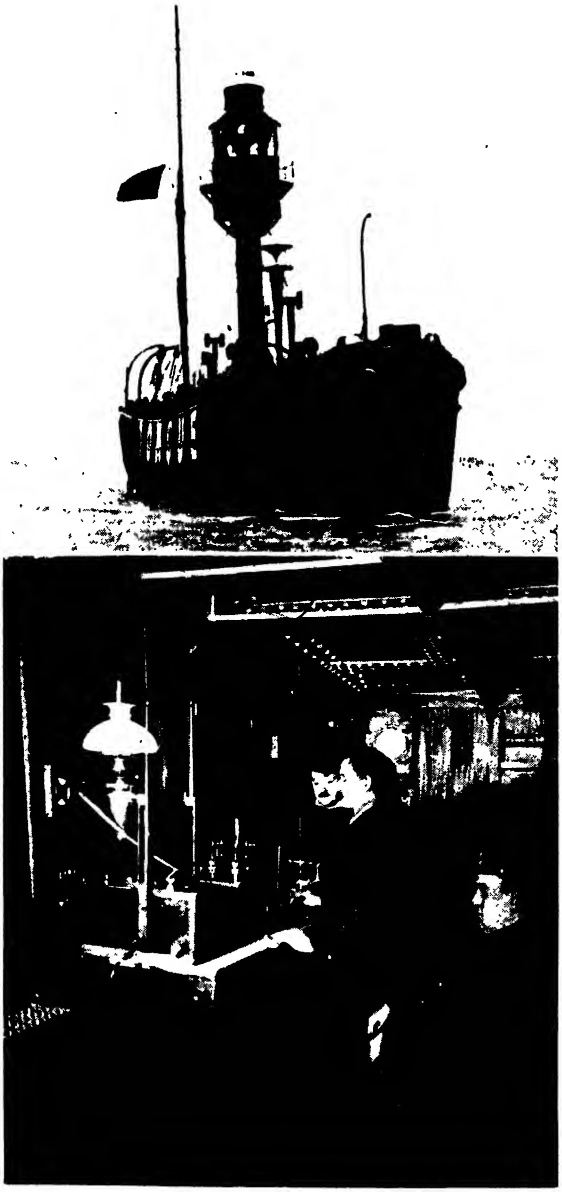
It will thus be seen that the principles underlying the science of wireless telegraphy are still far from being clearly ascertained. The matter is still in an experimental stage, and every important advance has to be worked out by long and costly tests. For instance, when the great Transatlantic station at Glace Bay in Canada was completely constructed, the wires formed a huge inverted and half-open umbrella frame. It was an immense funnel of wires running down from the sky to the earth. It was found, however, that when the wires were arranged in this shape they spread the electric energy in a circle over all the earth. Some of it went to the North Pole and some to the South, and some rippled over Canada and the Pacific Ocean. Yet only the very small fragment widening and thinning out across the Atlantic Ocean and affecting the instruments in the Irish station, was actually useful in sending messages. So it became necessary to devise a means of directing a wireless electrical current so that it should go straight to a certain spot thousands of miles away. This was done by taking down all the wires at Glace Bay, and arranging them in a different manner. In the latest stations the wires slope for some distance up into the air like an inclined ladder, and then stretch out in a long narrow level line pointing in the direction to and from which it is desired to send and receive electrical currents. In 1906 Marconi brought wireless telegraphy to a high state of efficiency by inventing a new and better way of creating electric waves. This he called

A NEW HOPE IN THE HOUR OF DANGER

SENDING WIRELESS MESSAGES FROM THE MOUNTAINS BY USE OF A PORTABLE EQUIPMENT

the persistent wave system. A powerful electric arc flame is formed between two small wheels; and a third large wheel, with adjustable projections, breaks sideways in upon the arc, and converts it into an extraordinary and regular number of separate, tremendous electric sparks that set up very rapid trains of electric waves of vast length.

At the present day there are at least half a dozen different systems of wireless telegraphy in operation— the Marconi, the Telefunken, the Poulsen, and the Fessenden systems being some of the best known. Most of them have a good deal in common; for there have been many exchanges of ideas, and in some cases Marconi has reason to believe that important principles which he first worked out in a practical way have been, to put it politely, borrowed by certain later inventors. Hence, law-suits. So now the directors of the great systems prefer to keep some of their recent improvements secret rather than patent them. For it is often easy, when a new idea has been worked out, for another clever engineer to use it in designing a piece of mechanism which is not covered by the patent. Yet, from the public point of view, little harm has been done by the rivalry of the various systems. The exchange of ideas, and the incessant stimulus to invention among the engineers and directors and advisers of the various companies, have largely helped in the marvellously rapid development of the latest and most useful form of telegraphy.

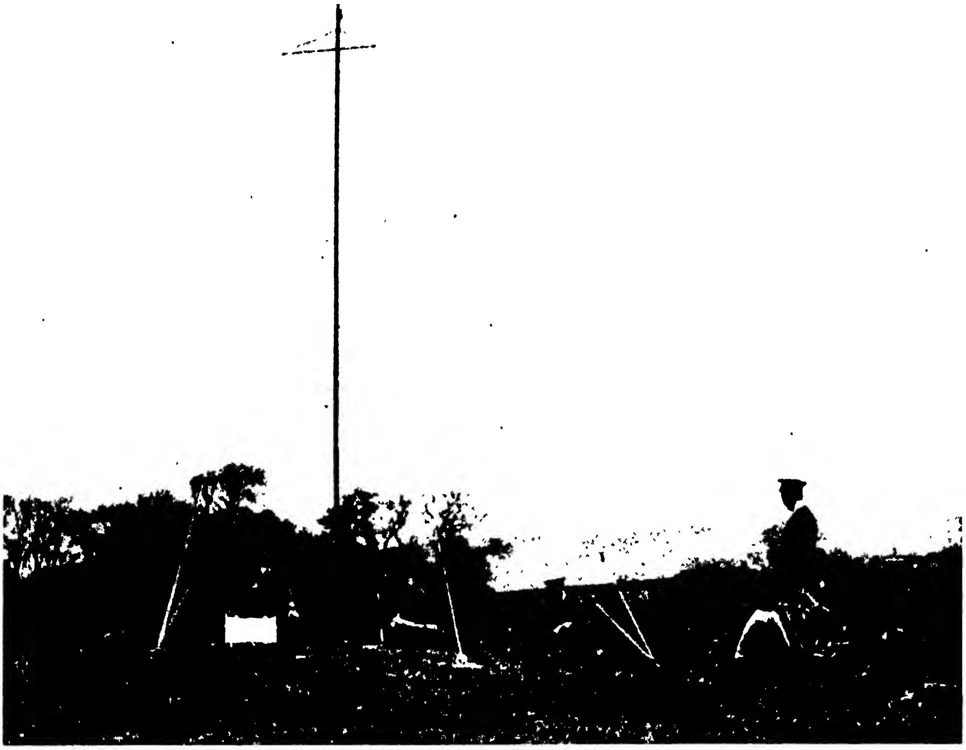


WIRELESS INSTALLED ON THE LIGHTSHIP

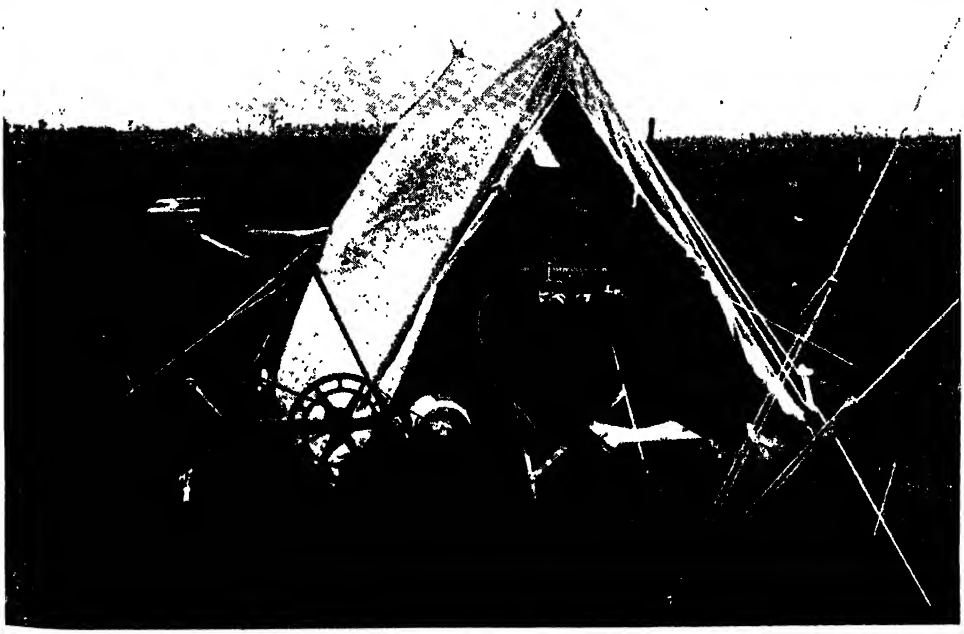
Of especial value in times of fog and storm is a wireless installation on a lightship; these two pictures show the aerial mast and operating-room on the Tongue lightship, which lies anchored at the entrance to the Thames.

And it is agreeable to find that, in spite of the presence of powerful rivals, sometimes supported by their Governments, the inventor of the first practical and public system of wireless communications is still in front of all his rivals. Marconi is in the happy position of being able to realise in the prime of his life the idea on which he has been working since he was twenty years of age. Very soon a chain of Marconi stations will be erected around the British Empire. For the agreement establishing this service was signed at London on March 7, 1912, on behalf of the Imperial Government and the Marconi Wireless Telegraph Company. As a beginning, six stations are now being erected at London, Egypt, Aden, Bangalore in India, Pretoria in South Africa, and Singapore in the Far East. The Marconi Company is receiving a payment of £60,000 for each station, exclusive of site foundations for machinery, and the buildings. And for twenty-eight years from the date of the completion of the first six

WIRELESS IN USE BY CAVALRY SCOUTS



AN INSTALLATION FOR SENDING MESSAGES FROM THE FRONT DURING MILITARY OPERATIONS



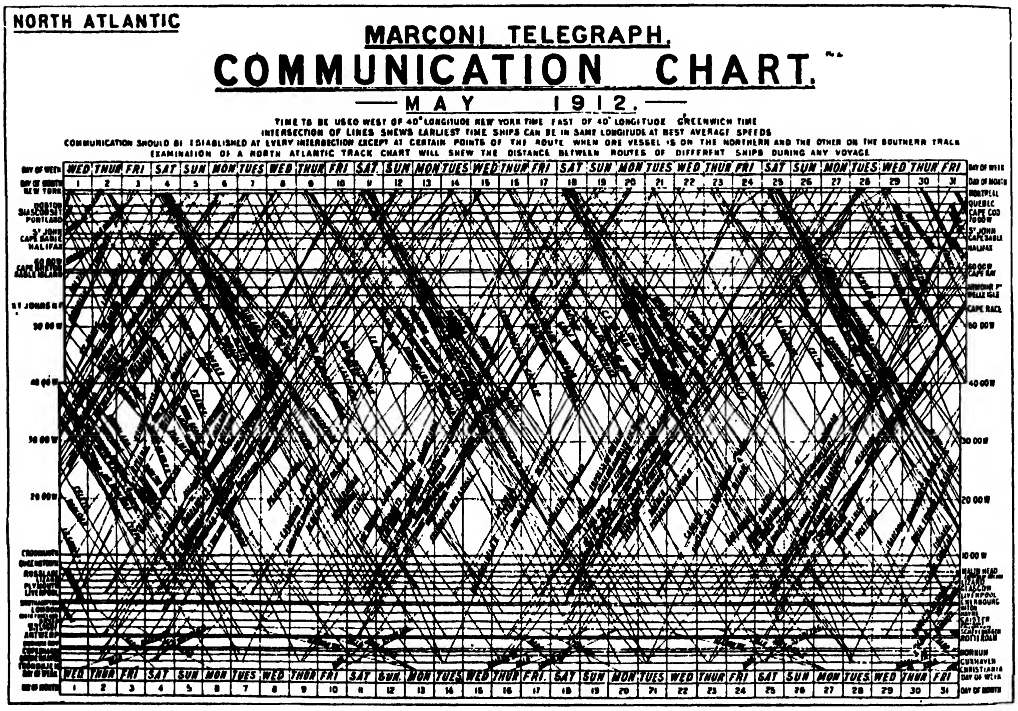
NEARER VIEW OF THE APPARATUS USED FOR RAPID TEMPORARY SERVICE IN THE FIELD

The photographs on these pages are by courtesy of the Marconi Wireless Telegraph Company, Stephen Cribb, Clarke & Hyde, the Dover Street Studios, and others.

stations the company will be given 10 per cent. of the gross receipts from all long-distance messages. The stations will be worked for the first six months by the company, and afterwards by the Imperial Government, and the Government will fix the scale of charges. These, it is expected, will be surprisingly cheap, as it is desired to promote the exchange of news and business and private communications between all parts of the Empire.

When the first six stations are in working order, the chain of Empire will be lengthened out until all the dominions and dependencies of the British people are linked together by a web of invisible electric currents with a speed of 186,000 miles a second. The instruments now being erected will send between 100 and 200 words a minute. To a great extent the Empire will become independent of submarine cables, and its new lines of swift communication will be such as no hostile cruiser in time of war can pick up and cut.

All this, however, is only a part of a greater scheme that Marconi has set himself to carry out. The agreement now concluded with the British Government will be followed by others of a similar nature with other countries, until all seas and lands are peacefully bound together by chains of wireless stations, with their subtle, strange and powerful web of electric currents radiating over the entire earth. A ship on the loneliest of oceans will then be able to talk to a port across the earth. Indeed, in a short space of time the Lords of our Admiralty will be able to control any fleet on this side of Hong Kong; and when all the Imperial stations are erected, they will be able to direct the movements of warships in all the waters of the world. Of course, in war-time communication may be interrupted by the destruction of a station. Yet some recent experiments in the arrangement of the transmitting wires go to show that it is possible to erect a new kind of station with low wires, which can be built inside a fortress and protected from bombardment.



THE MONTHLY CHART CARRIED BY A LINER, SHOWING THE VESSELS WITH WHICH IT CAN COMMUNICATE

On this chart diagonal lines are drawn through the approximate positions each vessel will occupy on each day while crossing the Atlantic. The intersection of the lines shows the time and longitude in which the vessels will be within speaking distance of each other if they have travelled at their average speed. It will be noted that the lines for the "Titanic" are on this chart for May, 1912, though she sank on April 15. The charts are necessarily printed for wide circulation well in advance.

The science of wireless telegraphy has undoubtedly been largely developed with a view to its use in land actions and naval combats. Our Admiralty saw its warlike possibilities in 1895, and with remarkable

THE MIDNIGHT CALL OVER THE ICY DEEP

THE POSITION OF THE "TITANIC" WHEN SHE APPEALED FOR HELP OVER 1000 MILES OF SEA

enterprise tried Captain Jackson's system before Marconi came to England. But it is to the cause of unity, peace, commerce, and to the noble work of the saving of life in shipwrecks that the new kind of electric current is dedicated. It is making the most dangerous seas almost as safe a road of travel as a railway line, and safer than a great London thoroughfare with its whirling streams of trams, motor-'buses, cabs, and petrol-driven carts. It is about three years ago since the disaster to the White Star liner the "Republic" revealed to an admiring world the power that a Marconi operator now possesses in saving the lives of a shipload of people. When 170 miles east of New York, the "Republic" collided in a dense fog with an Italian vessel. It was an even more dreadful scene than that which occurred a few weeks ago when the "Titanic" struck an iceberg on her maiden voyage across the Atlantic. For the fog that surrounded the 'Republic' made all hope of rescue apparently vain. Moreover, wireless operators had not then had the experience in shipwrecks that they now possess, and fewer vessels possessed the means of picking up a cry for help sent out by means of an electric spark.

WIRELESS TELEGRAPHY IN THE HOME: A KEYBOARD FITTED IN A DRAWING-ROOM

In addition to all this, the wireless systems of communication then had a curious defect. What this defect was is revealed in the log of the Marconi wireless station at Siasconset, Mass., which is worth producing for its high historic interest. The log begins ten minutes before the first dim flash, "CQD," which in the old language of wireless telegraphy meant, "Come quick, danger." SOS—three dots, three dashes, and three dots—are the letters now used instead of CQD, as they are less liable to be misread. "Saving of souls" is the operators' reading of the SOS signal. The log proceeds:

"6.40.—Hear MKC calling CQD. (MKC means the "Republic.") I sent back SS (Siasconset). He said he had been run down and was sinking rapidly. 'Send help quickly,' he repeated three times.

"I got busy at once, raised operator at Wood's Hole, told her to rush revenue cutter; she did it. Then I began to call CQD, getting LC ("La Lorraine"); told him of disaster; said he would speed to the rescue. Then got BC (the "Baltic," that went again, but vainly this time, on a wireless summons to the sinking "Titanic," then commanded by her old captain); he is doing the same.

"8.04.—Receiving MSG (captain's message) from MKC ("Republic"), saying he was rammed by unknown ship, and was sinking 25 miles south of Nantucket. No lives lost and not in danger.

"8.30 a.m.—Hear MKC answer BC, but RGG (revenue-cutter "Gresham"), using stronger current drowns everybody.

"8.45 a.m.—Had MKC. Tell MKC that BC and LC are rushing to her aid.

"Binns answered: 'Good. Tell them to hurry!'

"9.15 a.m.—LC ("La Lorraine") says our boilers are nearly bursting.

"9.15 a.m.—MKC reports passengers OK on board steamship 'Florida.'

"9.15 a.m.—Revenue-cutters and Navy stations are 'jamming thick.'" ("Jamming, in the telegraphers' language, means the diffusion of several strong currents which prevent a clear message by anybody.)

"9.47 a.m.—MKC says to listen for rockets.

"10.12 a.m.—Can't make out jammed messages.

"10.50 a.m.—Navy won't keep out.

"11.05 a.m.—Tell revenue-cutters to cut out and lay by.

"11.30 a.m.—BC ("Portsmouth") and ROD talking and jamming us right and left.

"11.40 a.m.—Navy insists on jamming. I gave them BY again (meaning "Keep quiet").

"1.32 p.m.—Have found the LA ("Lucania").

BRINGING THE EMPIRE WITHIN CALL

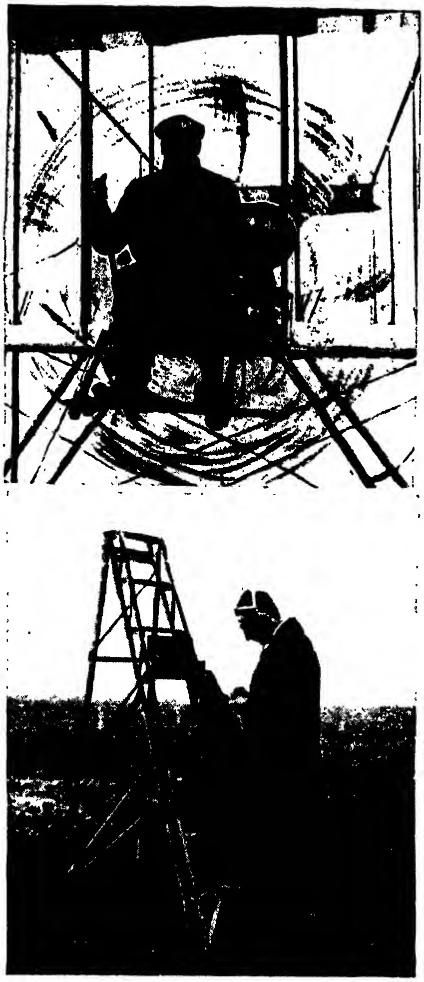
THE RING OF WIRELESS STATIONS NOW BEING ESTABLISHED AROUND THE BRITISH EMPIRE

FACING PAGE 2053

"2.05.—BC, LC, and LA scouting for signs of MKC. 'Florida' (the ship that collided with the "Republic") has no wireless.

"2.30.—BC asks CQ (all stations) to keep out, for God's sake."

What progress has been made in preventing jamming can be estimated from the fact that there are now two stations within eight miles of each other on the Irish coast which operate with scarcely any interference. Only about once in every seven hundred and fifty times is there any mutual bother. There are two ways in which the transmission of wireless currents is accomplished without disturbing the numerous instruments in the vast radius of action. Two connecting stations are built with electrical apparatuses that are attuned to one another. They use a wave-length different to the wave-lengths of other stations, and only their receiving instruments are responsive to this special wave-length. Then, again, the waves are grouped in a distinct manner, and this grouping gives them an individual character that enables them to work without disturbing the receiving apparatus of other stations.



SENDING WIRELESS MESSAGES FROM AIR TO EARTH

On the other hand, the original universality of the messages sent by wireless currents is a great advantage to a ship in difficulty. She wants to appeal to every vessel within her radius of action. In this case her instruments are designed so that they can be used with a general effect. It leads to "jamming" when amateurs interfere, but it makes for general utility in marine telegraphy. In many cases there is a kind of slide on a wireless apparatus, and by moving this slide the length of the waves can be altered. Several Governments are beginning to insist that all passenger vessels shall carry a wireless telegraph producing waves from about three hundred to six hundred yards long. And it is very likely that all seagoing boats will soon need a similar apparatus. For it is now proposed that lighthouses shall direct ships by means of wireless currents; and a French officer, Lieutenant Lair, has recently invented a wireless instrument for use in all the lighthouses in the world. A simple register, working automatically on board ship, will show the exact distance over which the signal has been sent. As each lighthouse will have a distinctive signal, a vessel in the densest fog will be able to ascertain exactly its position.

A great electric lighthouse on Lieutenant Lair's plan would merely cost £2000, and only two men would be needed to work it. The recording instrument for use on ships is also very cheap, costing about £60. So it is clearly in the interest of shipowners, underwriters, and insurance agents that this simple and inexpensive system should be introduced with little delay.

Crews and passengers should also interest themselves in the matter, for it is evident that the old lighthouse is now antiquated. Fog has always been the greatest source of danger on the sea, and, except for the wireless current, there is no sure guide for a fog-bound ship. Bells, sirens, and cannon-shot are soon deadened in the muffling woolliness of a fog, but a wireless lighthouse of the first class will send its signal thirty-six miles, and the signal cannot be misread, as it will be automatically registered on the receiving instrument.

THE WORLD'S WHISPERING GALLERY

THE FLASHING OF EVERY STORY OF THE HOUR, FROM "A' THE AIRTS THE WIND CAN BLAW," TO MANKIND'S AUDIENCE-CHAMBER—THE NEWS-ROOM OF THE DAILY JOURNAL

TELLING SOME NEW THING

The Stupendous Miracle of Collecting the World's Doings Hour by Hour for Sale Daily at a Halfpenny

THE STORY OF THE MODERN NEWSPAPER

Three hundred years ago, when Shakespeare had already reviewed in his plays nearly the whole range of human life, so backward was the common chronicle of man's doings that there was not a newspaper in the world. For the moment we have no great literature, but there are sixty thousand newspapers, and of these thirty-five thousand are published in the English tongue. Whatever may be its relation to literature, the newspaper Press is, at any rate, a great industry. Regarded only as a means of employment, without reference to its influence on business, politics, education, amusement, or morals, it is one of the most important, if not essential, businesses of the world, and as such must have its place in this work.

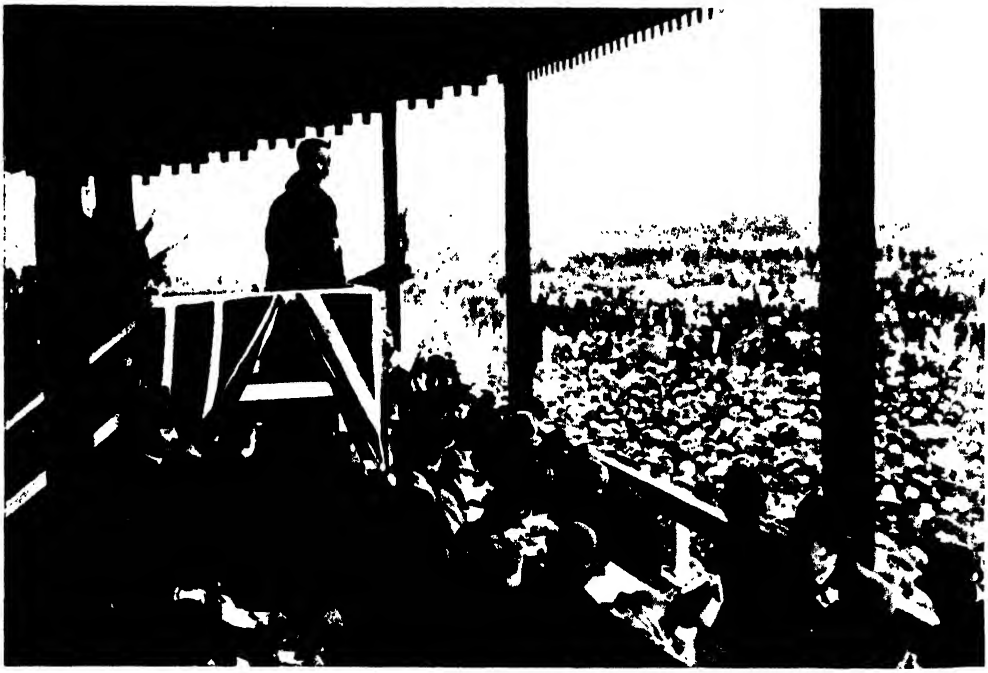
Rather curiously, there is no business of which the average man thinks he knows so much and really knows so little. He glances over his favourite newspapers with a discriminating air, judging loftily the completed product, but he has only the faintest notion of how it came to be. Nor is it likely he should have, for the field of the newspaper Press of today is so vast that comparatively few are wholly at home in it. In its latest developments the newspaper is a miracle, a portent, permeating all forms of society and yet not fully apprehended either as a fact or a possibility.

The governing idea of the Press of today is instantaneousness. In the newspaper world, as elsewhere, it is pace that wins. Whether superior wisdom goes hand in hand with superior swiftness may be doubted. In fact, probably every thoughtful person does doubt it. Half a century ago well-considered judgments were carefully offered to careful newspaper readers; today swift news is accompanied by equally swift opinion—opinion as swift in passing as in coming—but it is useless to grumble. The facts cannot be altered. We think far more admiringly of the speed of lightning than of its illuminating power. We must sate our delights in curiosity and in swiftness. We want simultaneous sights of everything that is going on in the world. To watch, to enjoy, to be moved, pleasantly or unpleasantly, is this not life? And if we have not imagination enough to be moved on our own account, we are grateful to anybody who can move us. This the newspaper man knows right well. It is his business to stir the average impervious man or woman daily as they wish to be stirred—sometimes with hopes, more readily with fears; anyhow, with sensations; and modern invention has given the newspaper man the power of serving the sluggish every hour. Wisdom! Who wants wisdom? It is interest men and women want, especially the newly emancipated millions of women—interest, and something to talk about!

The defeat and, indeed, annihilation of delay has given great intensity to the world's news as watched by the unimaginative. That something happened only yesterday, or, better still, only an hour ago, is gloriously exciting to many. The proximity in time seems to almost bring them to the place. Besides, we may even hope to actually see what has happened, rather fixed in expression, no doubt, and a little blurred by the printing of millions, but there it will be for anyone to see it without any need for the keener sight of the mind. Telegraphy along all the main routes of the earth; telegraphy palpitating wirelessly over all the wastes of sea; photography rewarded handsomely for "snapping" at every corner; improved machinery that can absorb news every moment, and print it in millions of copies; rapid distribution, regardless of cost, to all quarters of the land—all these things have come to pass

simultaneously, with such a measure of popular education as enables everybody to read the news flashed forth by an almost radio-active energy. From this conjunction of circumstances the modern newspaper has been born—born as a wonder that is as yet not half realised by those who most enjoy its ministrations.

Of course, we are thinking of the characteristic newspaper of the age; that is, the halfpenny journal. Happily for the completeness of our national record, there is still one threepenny daily paper; and there are also about a dozen or so of penny dailies with a substantial, if declining, influence. In every case, however, they exist either for issue, with a sufficient reason for its existence at either price, and the five times larger circulation of the halfpenny paper will be needed to pay, and will probably come. In so far as exclusive circulation is concerned, it is the halfpenny newspaper, on the whole, that has it. Comparatively few who read the higher-priced journals read them only. They consult the halfpenny papers as well, while very large numbers of readers of the lower-priced journals do not read any penny daily. Whether we like it or not, the characteristic newspaper of the age is the one sold for the smallest coin in general use, and that, therefore, is the type of newspaper we shall describe in this chapter.



THE REPORTERS' TABLE ON THE OCCASION OF A BIG POLITICAL SPEECH

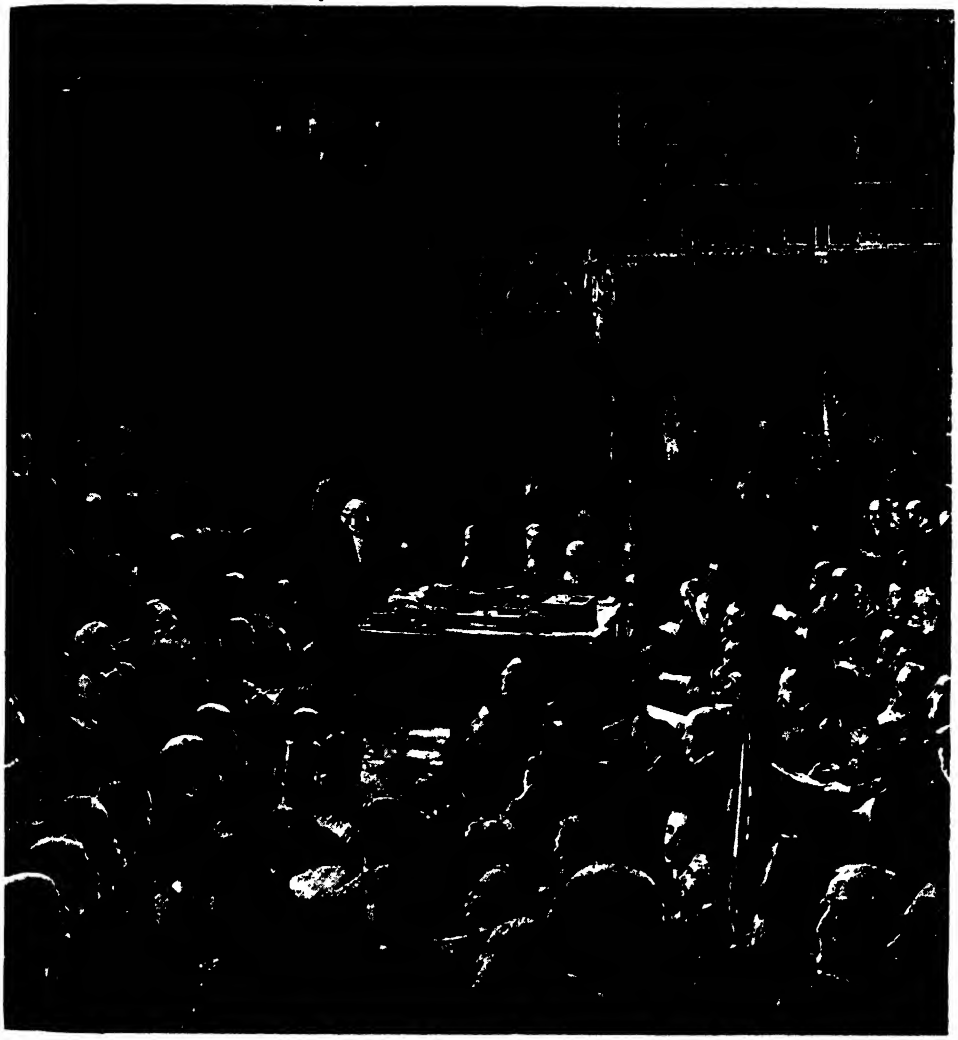
special reasons or as dwindling, though pecuniarily profitable, survivals. In scarcely a single instance can penny newspapers be said to be genuinely popular. They may be necessary in commerce, and they are a fuller repository of information than is possible to the halfpenny sheet with its restricted space, but, after all, the penny newspaper has become the organ of the classes, as classes. Only the halfpenny journal is for everybody, classes and masses alike.

As a matter of fact, the circulation of the halfpenny journal works out, naturally, at about five to one compared with the penny journal. Given a newspaper first sold at a penny, and then changed into a halfpenny

The first duty of a newspaper is to collect all the news. That may seem a tame statement, but it is a central fact of newspaper enterprise which the dabbler in journalism—political and otherwise—can never understand sufficiently. Ninety-nine people out of every hundred who talk most fluently about newspapers from, say, a party point of view believe that the first duty of the newspaper is to collect such items of news as may happen to interest *them*. They cannot understand how big the world is, and how diverse are its interests. They do not know the meaning of the word *news*.

What is news? News is any fresh matter that can be so presented as to be read with

avidity by the average man. Now, whatever has sufficient human interest to enthrall any considerable section of mankind has interest enough to catch momentarily the attention of the rest of men, provided it be told in the right way. It may be fact; it may be opinion; it may be discovery; it may be as old as the earth; it may be a chance triviality, but if it can be so told as to interest men spontaneously it is news—the last new thing heard that men can be persuaded is worth hearing. The newspaper plays up to man's avidity to hear things; it creates and then satisfies that avidity.



THE PRESS GALLERY IN THE HOUSE OF COMMONS WHEN GLADSTONE INTRODUCED HIS LAST HOME RULE BILL

The gallery in which the reporters of the newspapers sit is immediately above the Speaker's chair, which facilitates hearing, as all speeches are addressed to the Speaker.

To this end the eyes and ears of the journalist and would-be journalist are wide open in every nook of the world. The best observers are retained specially by the wealthiest journals to observe for them exclusively, and the rank and file observers are banded together in businesslike associations to gather up the news of the whole earth and wire it in bulk for wholesale newspaper consumption. These agencies pour all the news of all kinds—a mass of raw material—into every newspaper office in the land that will pay for it. And then, in addition, there are the regular staffs of

each journal searching ingeniously for something special to the journal itself; and the host of outside contributors eager to secure a market for their findings or ideas.

Can anyone who has not had inside experience in newspaper offices realise, even in faintest outline, what this nightly streaming in of news means? To place the raw material of the next day's newspaper issues on the desks of sub-editors every journalist of the world has been astir; every ocean cable has carried its cryptic messages; "All is well" or "Something is amiss!" has been sounded over the long line where the earth's civilisation and savagery meet; statesmen have been waylaid and questioned; universal justice has been watched with jealous eyes while it has upon whose tympanum falls every tone of man's passion and pride and folly, his grief and aspiration and exultation; and it is also a voice that may interpret these conflicting cries back to the world from which they came.

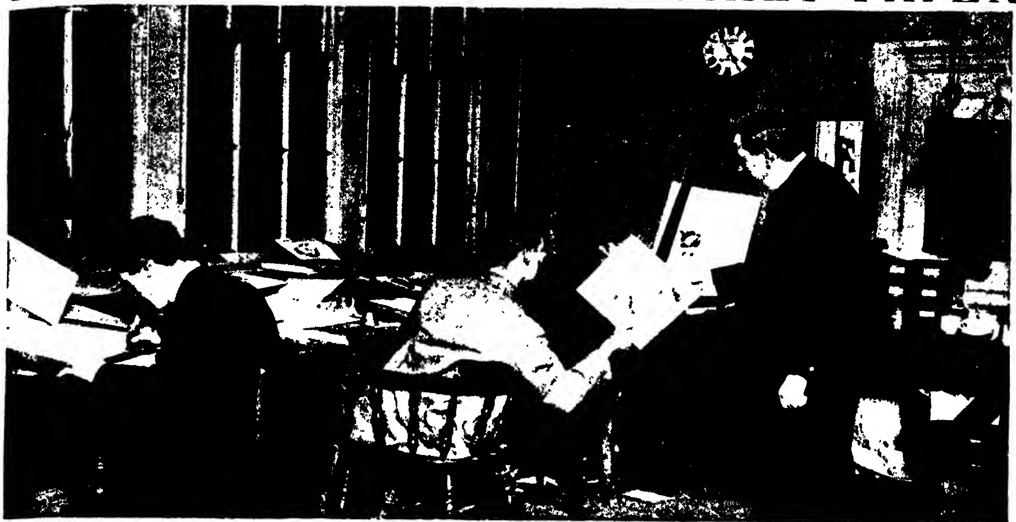
What is the cost of this collection of news--the raw material of the next day's issue? The reply, of course, will depend on the amount spent on exclusive information received through correspondents specially retained at the world's chief centres of interest--usually the great capital cities. On the whole, the cost of collecting foreign news has decreased with the changes in modern Press methods, except, perhaps in the cases of two or three journals that maintain their foreign traditions and staffs.

TWO HUNDRED MILES OF PAPER ARRIVING FROM NEWFOUNDLAND AT A GREAT NEWSPAPER OFFICE

worked for man's protection; the speeches that sow the myriad seeds of future change have been diligently transcribed; human passion in a hundredfold forms has been dramatised for human interest; Nature's strange fantasies, in storm or halcyon calm in drought or deluge, have been described from all distances; the results of man's labours and speculations have been collected and summarised for the guidance of commerce; the round of sport and pleasure has been recorded; and whatever man has publicly thought or done, or said or written, that can shock his fellows, or ennoble them with new hopes, has been transmitted, to fall into the confusion of this unsorted heap of the day's news. The newspaper is an ear

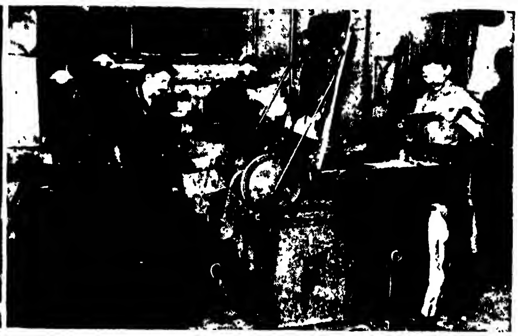
The plain facts of foreign occurrences are now forwarded by fully organised agencies for a fixed rate of payment, and individual collection of ordinary news becomes an expensive superfluity, though, in the most important centres, the trained, confidential correspondent holds his place with perhaps increased distinction owing to diminishing competition. It may be said without hesitation that the average daily newspaper of the British Isles gets its budget of foreign news daily from all the world at a cost that does not exceed the total of the salary and expenses of a single competent correspondent at one of the great European capitals forty years ago, before foreign "services" were fully organised.

PICTURE-MAKING FOR A DAILY PAPER

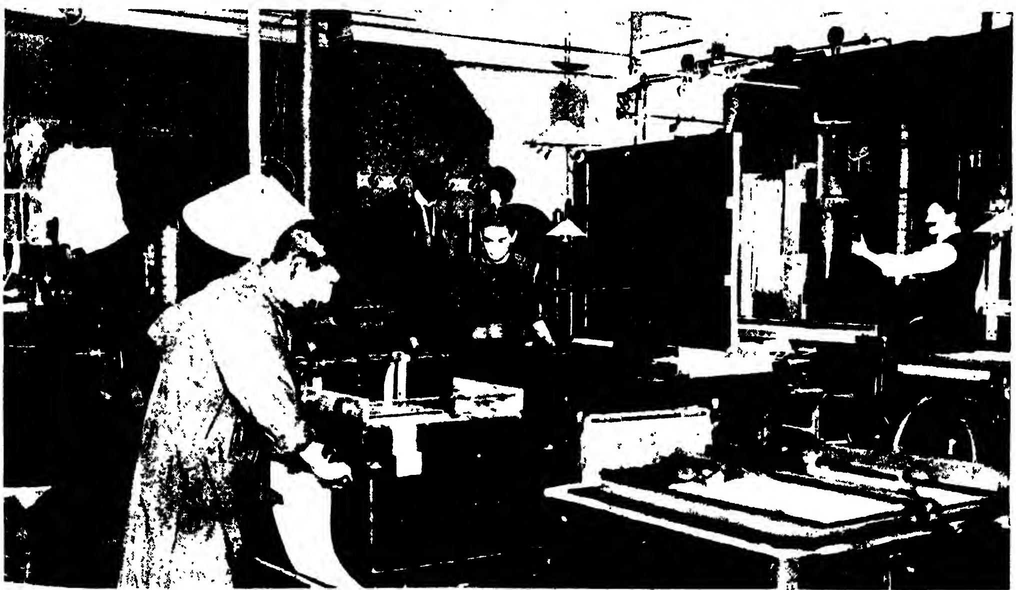


THE ARTIST'S STUDIO WHERE DRAWINGS AND PHOTOGRAPHS ARE PREPARED FOR PRESS

THE PROCESS-ENGRAVING CAMERA



ETCHING THE PROCESS BLOCKS



GENERAL VIEW OF AN ENGRAVING DEPARTMENT WHERE THE PROCESS BLOCKS ARE PREPARED

Of course, if occasion should arise for individual observation anywhere in the world, many energetic newspapers would quickly have their correspondents on the spot, but that is quite a different set of conditions from those under which every newspaper with pretensions to authority had resident correspondents doing regular work at Paris, Washington, Berlin, St. Petersburg, Vienna, Rome, Constantinople, and other capitals. The annihilation of space by telegraph and telephone, and the constant and intimate touch through commercial relations, have caused every rumour in a foreign capital to echo instantly round every other capital. Through general information, the newspaper office has its finger hour by hour on the foreign pulse. Why, then, should it incur the superfluous expense of a department of exclusive information, chiefly inferential? Inferences are cheapest when made at home, provided a sufficiency of material comes to hand.

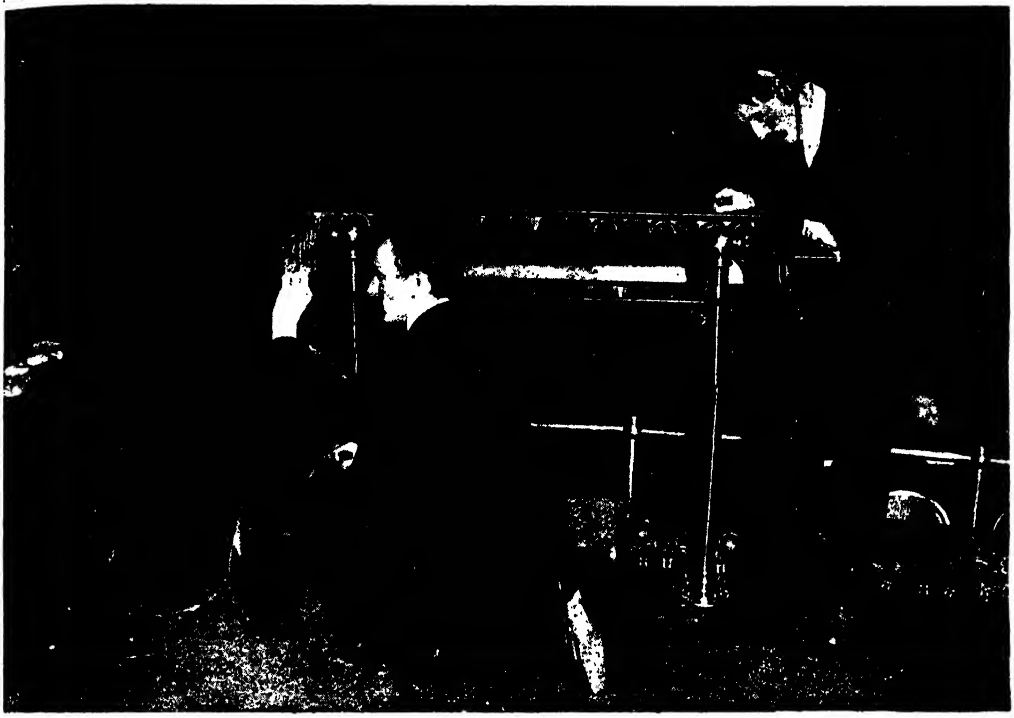
Let us suppose that the day's news has reached a newspaper office in the evening, in innumerable forms and by innumerable avenues, but largely and in the bulk the same to each office, because served out by the staffs of the world's reporting agencies. The mass has now to undergo two processes that may be described briefly as condensation and dressing up. Both these processes have been changed sensationally since the advent of the halfpenny paper. The inveterate ignorance of the public respecting newspapers is shown in nothing so clearly as in the ineradicable belief that what an editor wants is "something to fill his paper," whereas his difficulty is in throwing away twice as much as he can possibly use. We are not saying that times do not arrive when a supply of good news runs short. Indeed, a most striking feature of newspaper production is one that the amateur would not expect—namely, the tantalising fluctuations of genuinely interesting news. Not uncommonly, half a dozen events jostle each other for pre-eminence on a single evening, any one of them worth the chief line on a contents bill. Under these circumstances, events that only interest small groups of people are crowded out, much to the surprise of the reader who never observes that news items are competitive. The great fiasco of the Suffragettes, who had often been given space on slack days, came when they thought they could compete with the coal strike, and they were snuffed out of notice. The competition between news and news occurs with a complete irregularity.

THE TAPE MACHINES THAT BRING NEWS FROM ALL THE WORLD TO THE DAILY PAPER

Sometimes ordinary supplies run amazingly low in quality, and finding a "line for the bill" requires a dead-lift of imagination. The customary off-season comes between Christmas Day and Twelfth Night, if no accident has happened to the holiday traffic. The fact is that the watchful news-gatherers are then resting, like other people. This is the opportunity for the public-minded man who loves to gain the ear of the Press. He will be welcomed, instead of being ruthlessly condensed. But such a state of things is a holiday rarity. The rule is that the weeder of newspaper copy would be buried under the mass of matter projected at him from all parts of the world were it not for his practised dexterity in turning it into the waste-paper basket.

Every daily newspaper is blocked out into different departments, each filling a certain number of columns, according to the exigencies of the day. Thus there is the literary department, the ladies' page, sports, commerce, correspondence, politics—as in Parliamentary reports—but above all and around all, and more important than anything else, because in reality including all.

A NEW ROUTE FROM PLATFORM TO PRESS



FITTING THE ELECTROPHONE IN THE ALBERT HALL TO TRANSMIT A SPEECH TO DISTANT REPORTERS

REPORTING IN PRIVACY THE SPEECH RECEIVED FROM THE ALBERT HALL THROUGH THE ELECTROPHONE

An ingenious development of the telephone, the electrophone is proving of great utility to the journalist, who can sit in his office and listen to a speech that is being delivered many miles distant.

there is *news*. In the ideal paper every item would have a news value. The money fluctuations, the sports, the ideas of correspondents, the opinions expressed by the paper itself would be so expressed as to awaken general human interest and be news for the average reader, as well as for the specialist in the particular feature concerned. What matters to one should matter in some degree to all; and when it is made to seem to matter it becomes news.

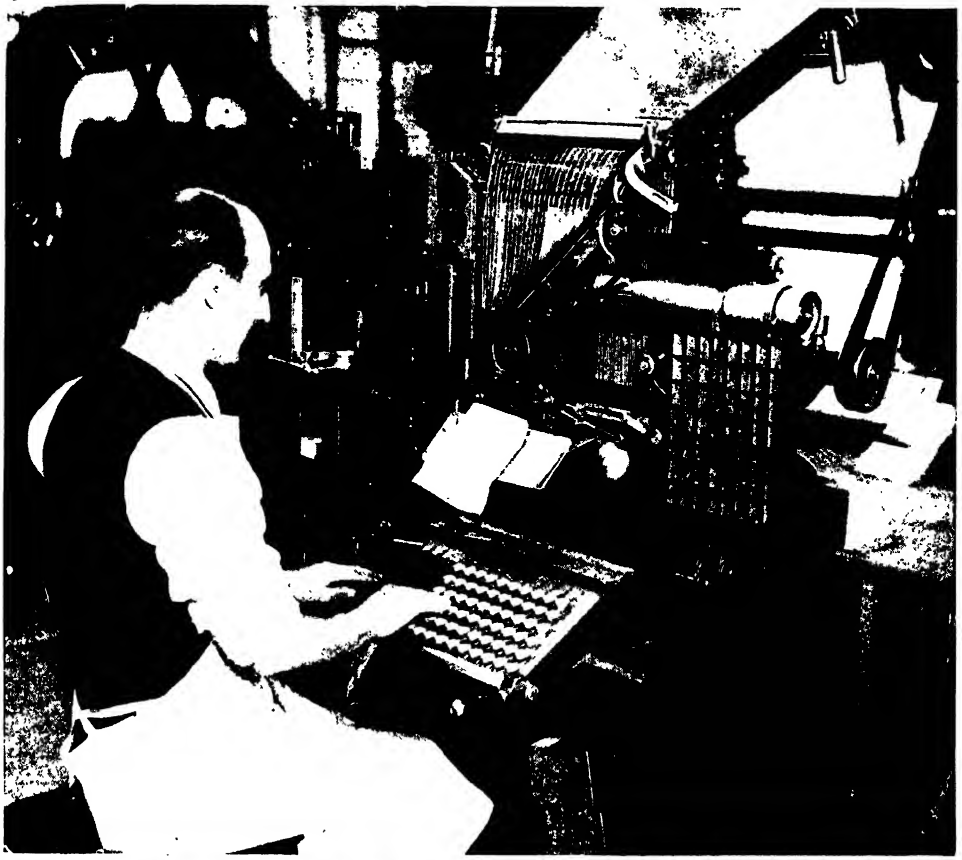
How can the man in charge of each section of the paper crowd into the impossibly small compass of his page, or half-page, report was sent in half a column long, on the subject that profoundly interests him, and who rages to see it cut down to ten lines, little suspects what a hostile gauntlet that attenuated paragraph ran, and survived. First of all, the advertisement department made preposterous claims on space that cramped the ordinary-sized paper without warranting an enlargement; and its temper was not improved by finding that some of its demands must be held over, after it had restricted the news to a minimum amount. Then, every department providing reading matter could make out an excellent special

THE NEWS DEPARTMENT, FITTED WITH EVERY DEVICE FOR QUICK RECEIPT OF INTELLIGENCE

all the news he feels is of importance? That is the problem which recurs everywhere and is never laid to rest. Of course, in a loyal and well-managed office every sectional interest should fit itself to each and all of the others like clockwork, and, in a sort of way, does so under strong guiding hands; but deep down beneath this fine unity there is a perpetual, natural, inevitable, and salutary jealousy. Peace reigns on the surface, but, on the newspaper, men's hearts are a battlefield in proportion as they are eager in their duty.

The innocent person who knows that a case for its full share of space, which finally became so restricted that nobody could be quite satisfied. What hope had half a column of coming intact through that strife? None, unless it could rise to the dignity of a readable Special that must not be delayed. Under these circumstances every unessential word must go. Finally, a judgment that surveys the whole paper must say which of certain conflicting claims shall be the survivor. In any case, it is a question, in the halfpenny paper, of skilful and inexorable squeezing, so that the pith of the whole day's news may appear.

THE MACHINE THAT MAKES AND SETS UP TYPE



THE WONDERFUL LINOTYPE MACHINE, WHICH INCREASES MAN'S EFFICIENCY FOURFOLD

GENERAL VIEW OF A NEWSPAPER COMPOSING-ROOM, WITH LINOTYPES ON THE RIGHT, AND ON THE LEFT A COMPOSITOR AT HIS CASE, SETTING TYPE BY HAND

But just in the proportion that cutting down occurs, dressing up is necessary. News that has become only scrappy and matter-of-fact has been spoiled. The problem is to retain interest while losing space; to suggest whatever dramatic quality the news contains, and brighten the recital, if possible, as it gains in brevity. What a splendid compliment Mr. Punch paid when he suggested that contents bills are more interesting than newspapers! There we have the ideal of intensity in condensity. The writing of headlines is the most practical of all journalistic arts. Some may object that the presentation of the news in stimulating headlines and arresting summaries is only the trimmings of journalism. But so far as the bulk of the day's facts are concerned it makes all the difference. The same fare is variously dished in the news-

HAND-SETTING SPECIAL TYPE

journals with which they differ most widely in opinion? They do it, everyone knows. The faddists do it in their tens of thousands. No more axiomatic statement can be made than that the faddist is an arrant fraud in relation to journalism. He will weep over sporting news, and plead for its extinction; he will insist on the moral necessity for the narrowest restrictions in the organ he professes to support; but that organ is never quite good enough for him, so he only buys it to find fault with it, while he sedulously reads and practically supports the lively newspaper which he thinks he hates, but which pleases his palate notwithstanding its lack of the moral fervour he affects.

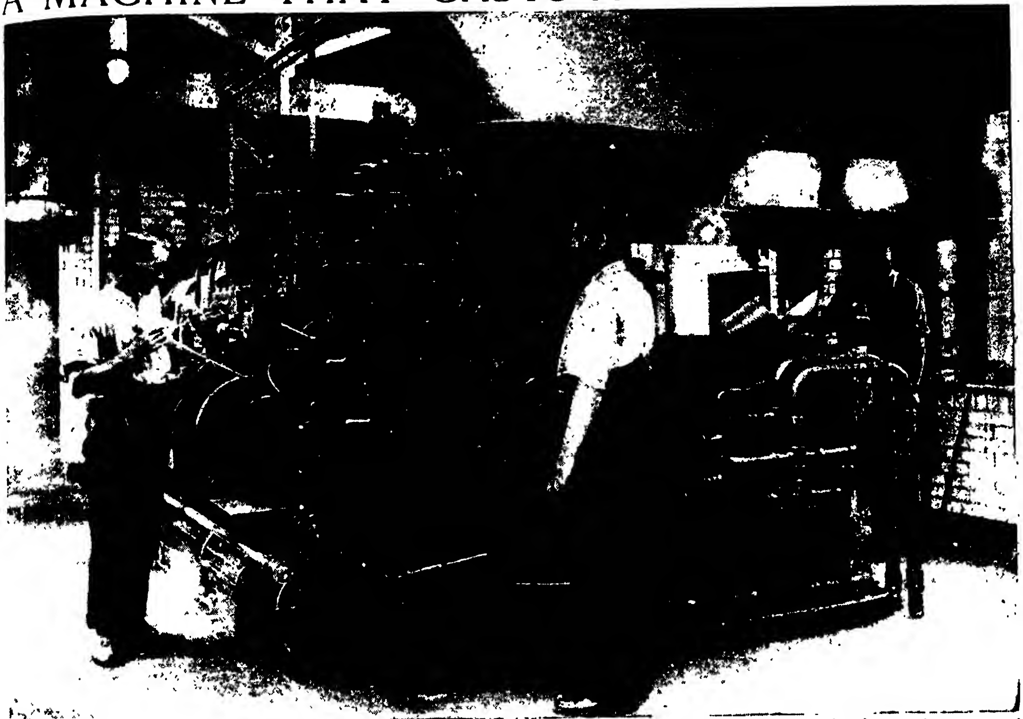
The dressing up of news involves, of course, much more than the writing of headlines and substitution of piquant narrative for the dull horror of common newspaperese.

MAKING UP THE PAGES OF AN EVENING NEWSPAPER

paper world by different cooks, and everybody likes the most "tasty" cuisine. If that is not so, why is it that so many people persist in reading, year in, year out, the

It involves suggesting to the reader all he should know for an understanding and appreciation of the news, and doing it in such a form that it flashes pleasantly on the

A MACHINE THAT CASTS A PAGE A MINUTE

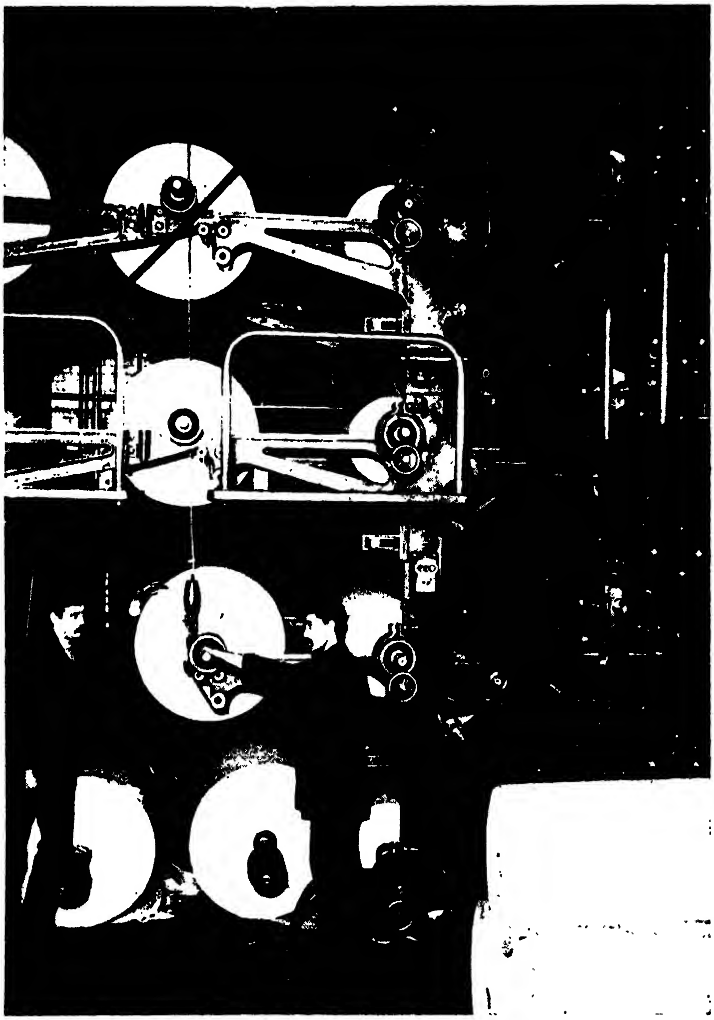


The casting end of the Autoplate. On the right is a cauldron of molten metal ; in front the curved receptacle for a dried paper-mâché matrix of a page of news. This is drawn forward into the machine

The delivery end of the Autoplate, showing solid metal pages that have been automatically cast and trimmed by the machine. Three of these machines in the "Daily Mail" office cast per hour two hundred of the curved metal pages from which the news is transferred by printing to paper.

inward eye, and makes the reader feel he has found out something worth knowing.

In this connection come all the added articles and presentations of opinion that give a newspaper much of its personality. Increasingly they are dressings for news, the sidelights thrown on news, the expansions necessary for a fuller interest in what is happening in life or thought. The sermonic treatment of the topic of the day in formal leading articles is as dead as the hour-long discourse from the pulpit. And the prophetic treatment, by writers lashed daily into a party passion, cannot long survive its inevitable mistakes. But the comment that is illuminating, explanatory, illustrative, suggestive of reflection, must remain to give weight to newspaper impressions however hastily they are gathered; and these comments will keep a place for the leader-writer along with the reviewer, and critics of the arts.



RANK ON RANK OF MONSTER PAPER-REELS FOR FEEDING A MODERN PRINTING-MACHINE

Let us suppose, then, that all the materials for the next day's issue have been delivered—the mechanical matter, such as market reports and money market quotations; the general news of the homeland sent in by three or four news agencies, and supplemented possibly by private reports from enterprising unattached journalists, and by special descriptions from members of the newspaper's own staff so far as the most important foreknown events of the day are concerned; that the due quantity of interesting literary matter glancing over human life and thought, and art, has been arranged for; that home-reading is provided for home-makers; amusements of all kinds brought under review; and that some fiction is in hand for the many people who read daily tales, but whom no one ever knows—suppose all this material is collected, what happens to it?

The mechanical production of newspapers has been revolutionised in every part by machinery during the last quarter of a century. The setting of the matter in type is now almost entirely done by machinery, each machine being worked by an operator, who sets from three to four times as much "copy" as could be dealt with by hand. The number of linotype machines available in a daily newspaper office varies from a score to about three dozen, and each of them costs, with its varieties of type, between £500 and £600. The ordinary newspaper printer of today, on routine work, is, in short, an "operator" working a £500 machine.

The linotype is so called because it casts a line of type solidly, and not in separate letters, the letters being arranged, before

the cast is taken, by a typewriting action. The pressing of a letter on the keyboard brings down, from a reservoir of assorted letters, one that is indented in metal, and places it in position. The next pressure brings down the next letter needed, till a line is formed. Then a solid cast of the whole line is taken in relief, the letters standing out ready for printing. After the casting, the indented letters that have been used are mechanically handed back by the machine to its reservoir, and are sorted into their places for future use. Thus the actual letters brought into play by the operator travel round and round in the machine. The casts in lines are much more easily handled than ordinary type, but every correction of a letter or punctuation-mark involves the resetting of a whole line.

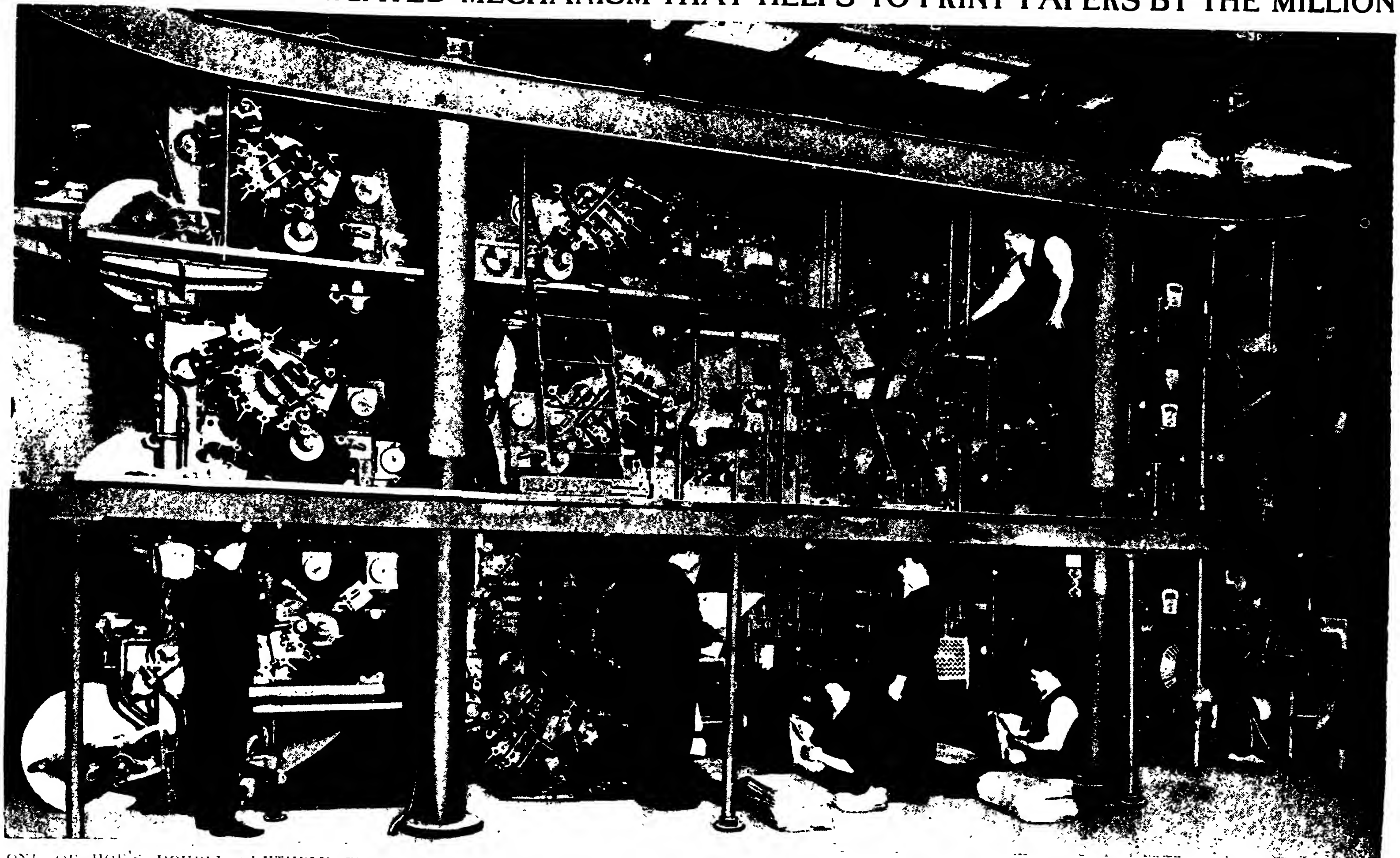
The type-setting machine has greatly quickened, simplified, and cheapened newspaper setting, but it has not affected the next step—the "make-up." The arrangement of the columns into pages, after the component articles have been headed and corrected, remains purely a printer's task, under the general direction of the sub-editor of the page concerned. From the point of view of the mechanical producer of a newspaper the *page* is the unit of action. While the news editor and literary staff are concerned to get into the paper as much as possible of the most interesting news, presented in the brightest form, the actual printer is mastered by the thought of getting his pages complete, one by one, and leaving as few open for news and change as may be; and it is in his department that the greatest advances in rapid newspaper production have been made.

The greatest essential of the popular press of the day, on the mechanical side, is rapidity of printing. Put into figures, that means that a successful halfpenny morning journal must print from a quarter of a million to a million copies in from two to five hours, between midnight and the time when people begin to move to their daily work. A large part of this circulation has to be printed in time to catch trains that start in the very small hours. In the case of evening newspapers more frequent

EXAMINING THE FIRST DELIVERIES OF AN EDITION PRIOR TO A RUN OF MANY THOUSAND COPIES

editions must be run off to suit the starting times of more frequent trains, and other agencies. The problem of speed is not the problem of spreading the printing of so many hundred thousands of copies over the period when the night's news—such as the last division in Parliament—ceases and the time when newspapers begin to be read in the morning, but it is the problem of

A MARVEL IN COMPLICATED MECHANISM THAT HELPS TO PRINT PAPERS BY THE MILLION

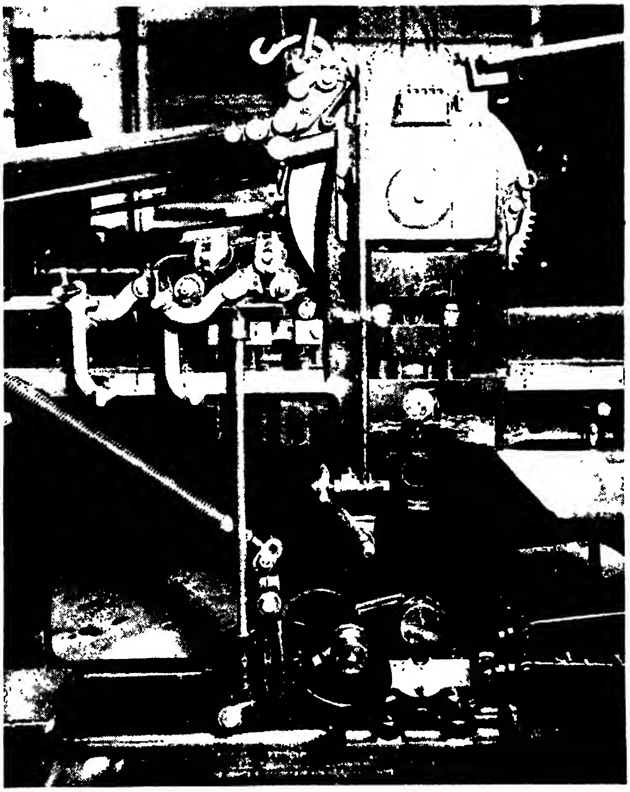


ONE OF HOE'S DOUBLE SEXTUPLE PRINTING-MACHINES IN THE "DAILY MAIL" OFFICE THAT PRINTS 120,000 TWELVE-PAGE PAPERS PER HOUR

running off the largest number of copies that will be needed between the most pressing train-times. Half a million copies, say, have not to be printed in five hours, but three hundred thousand of them in one particular hour, or else the papers will be late and miss their market.

How is the requisite rapidity secured? The speeding up has come by way of two inventions, one comparatively old now, but worth explaining to the general reader, and another comparatively new.

When a page of the paper—which is the unit of management—has been "made up," and clamped together in a metal frame, it is flat and rigid. The first invention that enormously increased speed in printing changed this flat rigidity into a round or cylindrical form, so that the page could be printed from with a swift circular movement, instead of being moved slowly backwards and forwards on the flat. This rotary printing is attained by taking a cast of the page, by pressure into a soft, thick, prepared felt-like sheet, which retains the indentation of every letter, and can be dried quickly into hardness and stiffness, while it will bend into a semi-circular form. Placed inside a circular metal mould, face inwards, this sheet serves as the matrix for many metal casts or plates. Molten metal passes into the mould and takes a rigid semi-circular shape, with every letter and comma of the page marked in raised type on its outside. The flat rigid page has thus become a rigid crescent-shaped page that will fit half way round a cylinder with a similar circumference.



THE CYCLOMETER THAT AUTOMATICALLY RECORDS THE NUMBER OF COPIES PRINTED

The eight, ten, twelve, twenty, or more pages of the paper thus transformed from their matrices into semi-circular rigid metal casts are placed on the cylinders of a machine and are ready for the final process of printing on paper. But every page may be cast from the same matrix again and again, and placed on additional printing-machines, so that, from one original setting of the type of a page, twenty metal casts or plates of the page may be put on twenty machines, and each machine may pour forth many thousands of copies per hour as they simultaneously unwind their five-mile long reels of paper, and by marvellously adjusted mechanism ink the type, print all the pages in order, cut them, and deliver them folded and counted ready for sale and reading.

It is the rapid multiplication of plates, so that any number of printing machines may be at work, swiftly and simultaneously, that is the second secret of the enormously quickened production of newspapers.

In the case of the evening newspapers, the quickening of these processes of preparation and printing becomes vital to great success; and ingenuity has been carried to its farthest point in quickly drying the matrix, and in swiftly producing from it, by mechanically fed casting-machines, as many plates as are needed; while capital is expended lavishly in building numerous and enormous printing-machines that will produce as many copies of the paper as can be ever required in any given space of time. Thus, the "Daily Mail" is equipped with machinery on the supposition that one and a quarter million copies

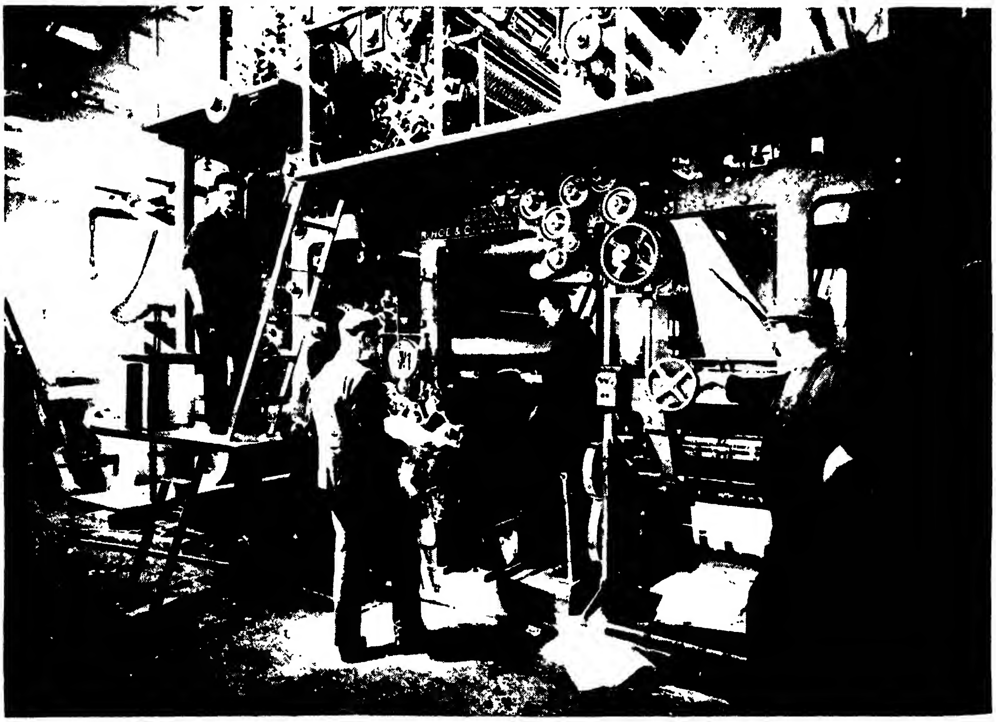
of each issue may be required, and may be so required that the printing of a large part of the issue would fall within a comparatively limited period of time.

The blank space left for the latest news is filled in after the cast plates have been placed on the machines, so that the delay of casting is avoided for the items of intelligence that reach the office while the machines are actually running. Such events are set in type on a segment of a column bowed round to the shape of the machine cylinders, and fitting into a space left vacant.

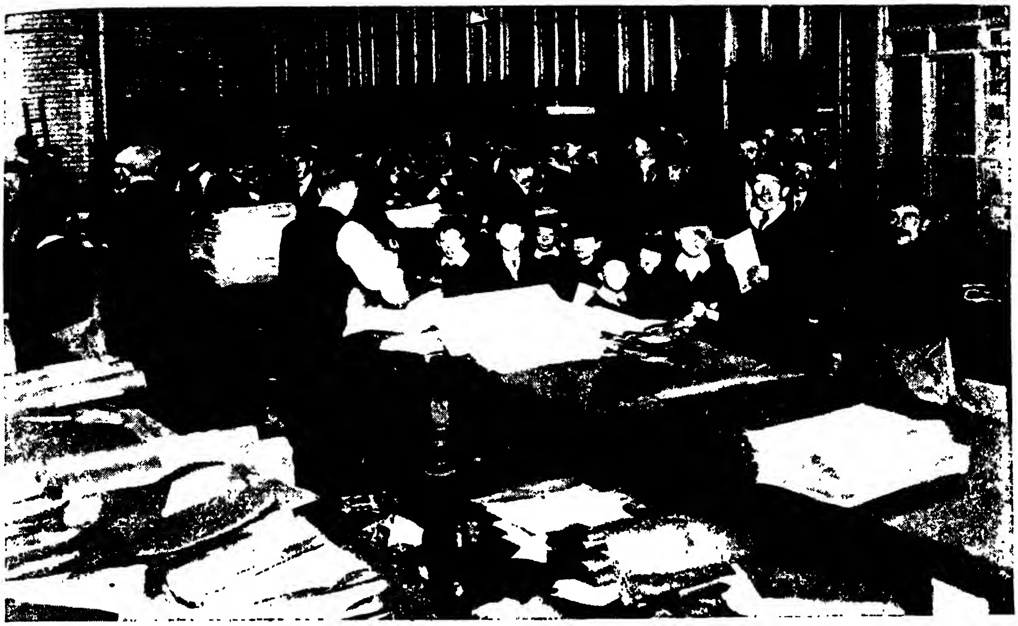
The swift distribution of newspapers is one of the most difficult problems of management. Some journals join to engage special trains. In the case of the "Daily Mail" and "Daily News," the printing is repeated in Manchester, so as to secure early distribution in the North. But the methods of dispersal are in no case so onerous with morning as with evening journals. As a rule, the morning newspaper prints the most substantial part of its circulation on one unchanged edition, and only reaches each district of the country by one morning train, whereas the evening journal must issue four or five editions that involve several repetitions of the processes of circulation, and so the expense of distribution is largely repeated. So costly is competitive evening distribution that, in some of the great cities, an agreement is made that rival journals shall sell their different editions at certain fixed points, at times previously arranged, instead of engaging constantly in ruinous racing.

There are phases of newspaper production of the highest importance that can only have a bare mention here, as, for example, the indispensable advertisement department, with its colossal income thoroughly well earned. Suffice it to say that, high as the prices of advertisement range in the most widely read journals, it would cost any advertiser probably three times as much as the price of his advertisement if he were to try—irrespective of the cost of printing it—to give it away to all the people who may notice it in one daily newspaper. It is as an agent of spontaneous and universal *circulation* that the newspaper has its business value. Only the newspaper or magazine can put straight into people's hands the announcements that bring business.

The production of the contents bill of a "Daily Mail" is as great an enterprise, judged by its consumption of paper and of energy in printing, as the total issue of many a provincial daily journal that is regarded as



PLACING THE CURVED PAGE-PLATES ON THE CYLINDER OF THE PRINTING-MACHINE



THE PUBLISHING DEPARTMENT FOR THE STREET SALE OF AN EVENING NEWSPAPER

successful. The ink used in the machining of that paper is siphoned by the ton into the printing-room, about twelve tons of it being used each week on ten thousand miles of paper.

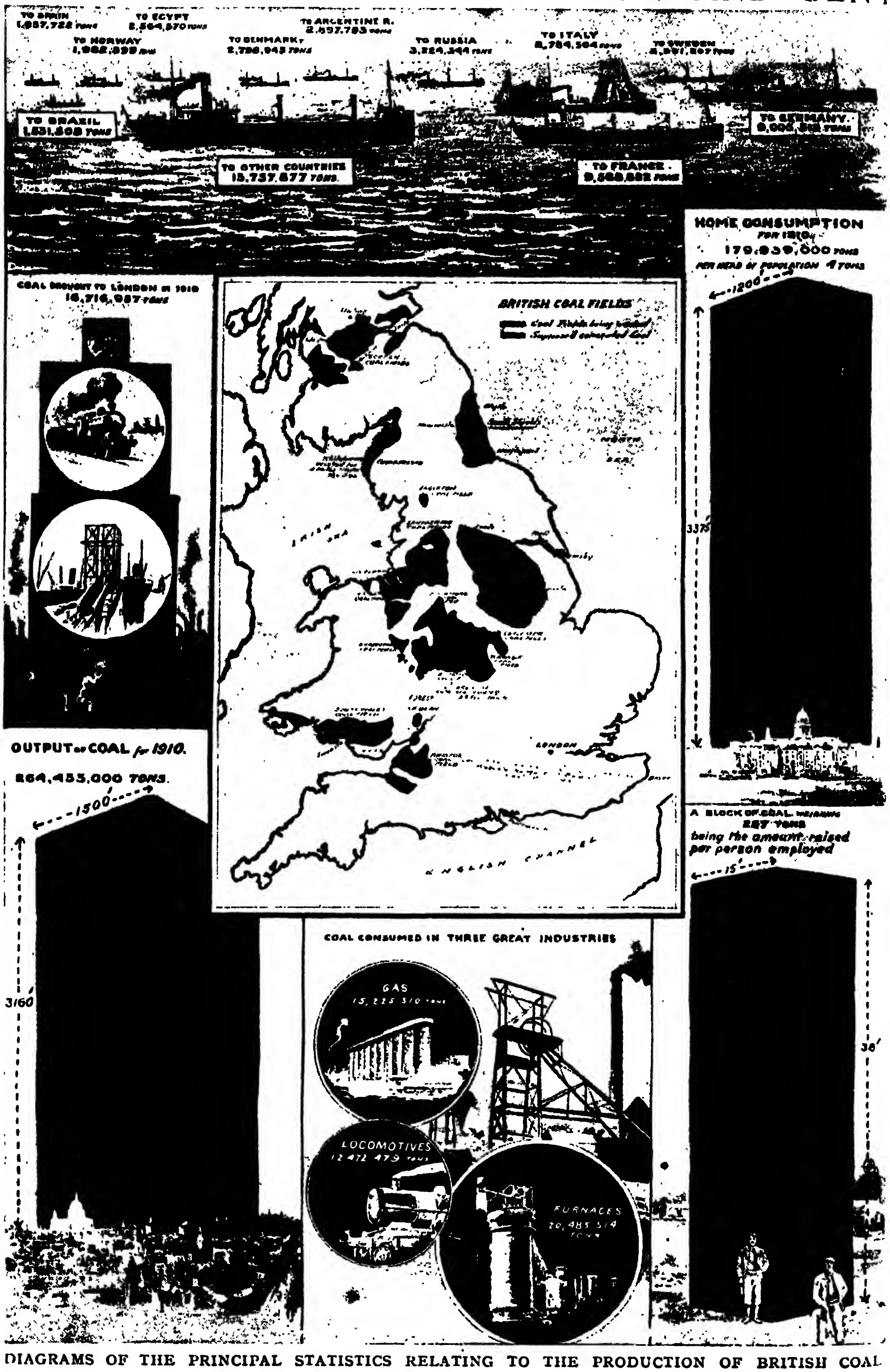
In casting page-plates for the "Daily Mail" and "Evening News" three Senior Autoplate machines are used, and they can cast more than three plates per minute. Each week about eleven thousand page-plates are cast. The printing-machines will take at once 832 plates, made up of over twenty tons of stereo-metal, and when so loaded have a printing capacity of more than a million copies per hour.

But wonderful though the material statistics of a great newspaper office must appear—more wonderful, perhaps, to those who know the details of production than to those who do not know, and cannot adequately conceive them—the mental miracle of a newspaper's message is strange beyond all that can be expressed by mere numbers. Let us guard against the dulling power of familiarity, and realise afresh all the transmutations through which a single moving message may come to us in our morning newspaper from, say, one of the great voices of our race speaking at a distance of half the world's circumference.

A statesman speaks. The mystery by which thought is formed is yet unplumbed, and its expression in clear and graceful words has taken the race æons to achieve, but words are articulated and live for a brief moment in the resonant air before they impinge on the ear of a recorder. Apprehended by his mind, they pass thence through the practised muscles of his hand, and take the shape of shorthand symbols, to be presently changed to longhand symbols, and in that form reach the telegraphist. Gathered up afresh by his mind, they reissue in the symbols of the Morse code, and so are flashed over "the great level plains of ooze, where the shell-burred cables creep," to be received and retransmitted under oceans and over continents till they are ticked out from a telegraph-machine in the office of the newspaper.

Now mind, now sound, now mind again, then signs, then mind, then signs—sometimes ticks of sound, sometimes dots and dashes to the sight—they come to their last brain-passage through the mind of the linotype operator, who fixes the words in solid metal indentations, from which they are embossed, then inverted, then embossed, and then printed; and all these transmutations are being carried on from myriad regions, and represent a myriad of interests, wherever the world's news is being flashed to the Press. And the sum total of it, contributed to by tens of thousands of minds, from first to last, and costing as many thousands of pounds—if we include the aggregate of the day's news—can be bought any morning for a halfpenny. That is the most stupendous unrealised miracle of the Age.

WHERE BRITISH COAL IS WON AND SENT



DIAGRAMS OF THE PRINCIPAL STATISTICS RELATING TO THE PRODUCTION OF BRITISH COAL

BRITISH COAL CARGOES

The Invaluable Part Played in Great Britain's External Commerce by Her Shipments of Fuel

OUR SHIPS AND OUR COAL EXPORTATION

THE great coal strike of 1912 should at least have served to bring home to the mind of every citizen of the United Kingdom the great essential fact with regard to coal—viz., that it is impossible in practice for a country to depend upon imported supplies. There are enormous quantities of coal in the world, as we saw in Chapter 5, but during the threatening weeks of the great coal crisis *those enormous supplies were, for British purposes, without existence.* The rich stores of the United States, or even of Germany, could not be called upon to take the place of the fuel which British miners refused to get.

It is well for us always to remember that this truth remains, whether miners are on strike or not. A manufacturing nation cannot be run on imported coal. If it could, then every nation in Europe would be a manufacturing nation. The lands which, like Britain and Germany, possess cheap native power possess a natural advantage over other competitors, as was brought home to our minds by the coal strike. Let us suppose that the coal strike had unhappily proceeded indefinitely, so that all the coal stocks were consumed and Britain became coal-less. We get a mental picture of awful disaster, and we are driven to wonder what would become of the nation under such circumstances. Yet in such case we should be merely reduced to the condition that obtains normally in, say, Italy, for Italy has no coal to get. With this difference, however: that whereas Italy, having to get along without coal, has adjusted her economy in its absence, we, having coal, would find upon its sudden withdrawal our entire economy deranged, while in other natural resources we should be at a relative disadvantage and in an inferior position not readily re-adjusted.

The thinking man who wants a picture of the United Kingdom without coal can find it in miniature in some districts in the Midlands. In the Black Country today we may visit places where the cheap coal which spelt industry and population has been exhausted, and where ruined houses and grass-grown streets remain to remind us of the busy populations that have had to find fresh woods and pastures new. In Nottinghamshire, on a recent visit, the present writer found himself in a small town that in recent years had lost thousands of its population because of the giving out of the coal. It could no longer be worked commercially owing to the exhaustion of the best seams of the mines. In connection with the coal strike the public have been reminded of the existence of a number of mines just on the margin of profitable working; and in the course of but a few years these will be compelled to close down, not because the coal is exhausted, but because it is no longer worth getting in competition with better favoured mines.

The fact that coal is best used where it is got, because it is so costly to transport, would at first sight make it appear that *commerce* in coal is not likely to flourish. If coal could be carried at the cost of a small percentage of its value at the pit-head there would be an enormous foreign trade in it. If under such circumstances the coal-owning countries were willing to export, every nation would be demanding ample supplies for manufacturing purposes, and they would not be able to get it quickly enough to supply the demand. *The cost of transporting checks what would otherwise be our chief exportation.* In spite of the cost of transport we have a considerable commerce in coal, but comparatively little of this is the result of demand

for manufacturing purposes. The chief explanation of coal exports is the rise of the steamship.

The conquest of the sailing-vessel by the steamship is a very recent thing in the world's commerce. The contest is shown clearly in the following record, contrasting the progress of the steamship with the decline of the sailing-vessels.

THE CONTEST BETWEEN STEAM AND SAIL

NET TONNAGE OF SHIPS ON THE REGISTER OF THE UNITED KINGDOM

	Sailing-Ships. Million tons	Steamships. Million Tons
1850	3·4	0·2
1860	4·3	0·4
1870	4·6	1·1
1880	3·9	2·7
1890	3·0	5·0
1895	2·9	6·1
1900	2·1	7·2
1905	1·6	9·1
1910	0·9	10·4

It will be seen that as recently as 1880 there were far more sailing-tons than steam-tons on the register of the United Kingdom. In the ensuing ten years a remarkable change occurred, and by 1890 steam tonnage was triumphant, exceeding sailing tonnage by two millions. Since then the sailing-ship has almost disappeared, and there are now fewer than one million tons of sailing-vessels on the British register.

That is the main explanation of the great growth of British coal exports. Here are the facts relating to the growth of British steamships and the great expansion of coal shipments.

GROWTH OF BRITISH STEAMSHIPS AND COAL EXPORTS

	Steam Shipping.	Coal Exports.
	Net Tons	Tons
1880	4,000,000	30,400,000
1890	5,000,000	38,700,000
1895	6,100,000	42,900,000
1900	7,200,000	58,400,000
1905	9,100,000	67,200,000
1910	10,400,000	84,500,000

The idea that the United Kingdom exports her coal and thereby enables other nations to compete with her in industry is seen to be entirely a mistaken one. It is perfectly true that a small amount of British coal is used by Continental nations for manufacturing purposes, but it is really very small, and it cannot very well sustain industry of a competitive character.

Nor is it the case that coal forms a very large percentage of the value of our exports. In 1910 we exported £38,000,000 worth of coal. Let us see how this figure has grown, and how the value of our coal exports compares with that of our shipments of British produce and manufactures as a whole. The facts are clearly stated in the following table.

UNITED KINGDOM EXPORTS OF COAL AND BRITISH PRODUCE AS A WHOLE

	(1) Exports of Coal	(2) Total Exports of British Goods (including Coal)	(3) Column 1 expressed roundly as percentage of col. 2
	£	£	Per cent.
1850	1,000,000	71,000,000	1
1855	2,000,000	96,000,000	2
1860	3,000,000	136,000,000	2
1865	4,000,000	166,000,000	2
1870	6,000,000	199,000,000	3
1875	10,000,000	223,000,000	5
1880	9,000,000	223,000,000	4
1885	11,000,000	213,000,000	5
1890	19,000,000	263,000,000	7
1895	15,000,000	226,000,000	7
1900	39,000,000	291,000,000	13
1905	26,000,000	330,000,000	8
1910	38,000,000	430,000,000	9

In recent years the proportion of coal value in our exports of British goods has varied a good deal, but in 1910 it was only 2 per cent. more than was the case twenty years previously. Coal exports have grown very greatly, but so have our total exports.

If for 1910 we deduct coal exports from total exports of British goods, we get an exportation, less coal, worth £392,000,000, which is over £100,000,000 more than the aggregate British exports of 1900 inclusive of coal.

It should be clearly understood that by the coal exports here referred to are meant the actual outward shipments of coal consigned to oversea ports, and exclusive of coal shipped at British ports to replenish ships' bunkers. Thus it will be seen by the above table that in 1910 we exported £38,000,000 worth of coal. In quantity this represented over 64,000,000 tons. In addition, over 19,000,000 tons were taken aboard by British and foreign steamers at British ports for their own bunkers. The total exportation of coal from the United Kingdom in 1910 was thus over 84,000,000 tons.

This quantity was made up as follows.

ANALYSIS OF BRITISH COAL EXPORTS IN 1910

	Tons
Anthracite	2,400,000
Steam	45,200,000
Gas	10,100,000
Household	1,500,000
Other sorts of coal	2,800,000
Coke	1,000,000
Manufactured fuel (briquettes or patent fuel)	1,500,000
	64,500,000
Add bunker coal shipped by steamers at British ports	19,500,000
Grand Total	84,000,000

While our coal exports counted in value for only about 9 per cent. of our exports of British goods in 1910, it should not be imagined that that statement fully expresses the worth of coal exportation from the United Kingdom. As was briefly pointed out in Chapter 3, coal exports play an extraordinary part in British commerce. The very fact that coal is such a bulky and weighty article to transport makes its carriage of peculiar value to shipowners. A certain amount of coal, as we have seen, must be exported to enable steam navigation to proceed, and our shipowners reap a rich harvest from the fact.

Coal serves, in the economy of our commerce, to balance the weight of our imports and exports. Coal is the chief outward cargo with which our shipowners have to deal. That is to say, although in 1910 our coal exports ranked for but about 9 per cent. of the value of our total British exports, that 9 per cent. was of more importance to the shipowner than the remaining 91 per cent. A moment's consideration will show why this is. The 91 per cent. of British exports consists mainly of manufactured articles, and many of those manufactured articles represented small bulk for much value. It is bulk and weight which decide the cost of freight; and the enormous bulk of the 9 per cent. of British exports that consist of coal yields much more carrying profit to the British shipowner than the 91 per cent. of other goods, although the latter are worth nearly £400,000,000 sterling. Between three-fourths and four-fifths of the weight of British exports consist of coal; and that great weight serves to balance in outward cargoes the great bulk of food and raw materials which chiefly makes up our inward cargoes.

It follows that, because of this balancing of import weights and export weights, our shipowners are enabled to make profits on both inward and outward voyages.

But there is not only the shipowners' point of view to consider. Let us suppose that the coal exports did not exist: a large number of ships would still be required to bring to the United Kingdom the enormous bulk of food and raw materials, worth about 500 millions a year, which we import. The ships would come to British ports, unload their cargoes, and all they would have to take out again from British ports would be our large exports of manufactures. But those large exports of manufactures are not large in weight or bulk as compared with the enormous bulk of the inward shipments of food and materials. Consequently, the ships that came in full would have to go out in a large number of cases in ballast, for want of outward bulky cargoes.

What would be the consequence? As the services of the ships would be required, although the outward voyages were largely unprofitable, it is plain that the inward voyages would have to pay for both inward and outward working. The inward freights would therefore have to be much larger than they are now, and our food and raw materials would cost us more. Wheat, maize, beef, mutton, cheese, butter, cotton, wool, jute, hemp, timber, sugar, rubber, ores, and many other bulky or heavy foods and materials which might be named would all be enhanced in price, hitting both the ordinary consumer and the manufacturer.

It is difficult to exaggerate, therefore, the part which coal exports play in our wonderful commerce; and our export trade could not possibly have reached its present size if we had not had coal to export to furnish our shipowners with just that kind of cargo which they needed in order to work their ships profitably. If we go back to 1840, or even 1850, we find that more ships entered British ports with cargoes than left them with cargoes. At the present time the balance is the other way, and this is in spite of the enormous increase in our imports of bulky foods and materials.

Of course, the working of steamships in this way does not necessarily imply a direct exchange of an outward cargo of coal for an inward cargo of food or material. For example, a ship may sail with coal from a British port to Marseilles or Genoa, in the Mediterranean, from thence proceed to a South American port with a light cargo, and bring back home from South America

to a British port an inward shipment of corn and meat. There are also, of course, vessels devoted wholly to the European coal trade which go out with coal and return in ballast to Newcastle or Cardiff.

How Nations May Live in Ignorance of the Conditions of their Own Prosperity

The more closely British industry and commerce are examined, the more clearly we understand the intimate relation of our coal supply to our national economy. Unfortunately, this intimate relation is widely misunderstood, so widely that just before the coal strike of 1912 came to a head we found a financial writer telling the British public that if the miners struck we could be quite independent of them, since there was a heap of coal in the world, and we could easily import it from America or from the Continent of Europe. It needed but a few weeks to demonstrate the fallacy of the conclusion, but it is not without significance that it was possible for such a statement to be made. It goes to show that the citizens of a great nation may live in complete ignorance of the conditions of their own prosperity, and that therefore it is possible for a nation not to comprehend exactly what is happening when it is in extreme danger. This was true of the ancient world, and it is perhaps even more true of the modern world, because of the extreme complexity of affairs. Great and main issues become obscured by an embroidery of minor matters; and the divorcing of trade from trade, and of profession from profession, causes even men of intelligence to lose the power of co-ordination.

The Inherent Antagonism Between National Conservation of Resources and Present Trade

In view of the great part which our commerce in coal plays in the development of our shipping and commerce, the maintenance of coal exportation is seen to be a matter of very great importance to the United Kingdom. The facts of the case present a curious problem. A vast further expansion of coal exportation would mean an immediate and enormous gain to us, but it would also mean a more rapid depletion of that most easily won part of our coal resources which gives us our great relative advantage in manufacturing. Even as the matter now stands, between coal exports proper and bunker coal taken in by ships at British ports, we have seen that we send out about 84,000,000 tons of coal per annum. Our total production of coal, as we saw in Chapter 5, is about 270 million tons, so that we already actually export about one-third of the coal that we raise.

Surely a nation was never faced with a question of greater difficulty. It is obvious that if we had no coal exports the consumption of our best coal would be so greatly reduced that our greatest resource would be conserved, and the exhaustion of our cheap coal greatly postponed. On the other hand, if we enacted the prohibition of coal exports, we should strike a deadly blow at our shipping and at our trade generally, for the reasons already given. Moreover, if we did so, we have no guarantee that posterity would gain anything by our present self-denial.

Who shall say how long manufacturing industry will be dependent upon coal for motive power? Here is a question which it is impossible to answer with any confidence. Yet the balance of probability is that either we shall learn so greatly to economise coal that much less of it will need to be used, or that science will place at the disposal of mankind forms of power-getting which will make coal entirely obsolete. Either of these considerations raises points of the greatest interest and importance for the United Kingdom in particular, as well as for the world in general.

Coal Conservation Best Served by Economy in the Utilisation of Fuel

First let us consider the matter of conservation. Curiously, economy of the use of coal stimulates demand; and it does not necessarily follow, if science made it possible for one pound's worth of coal to do as much work as is now done by four pounds' worth, that the consumption of coal would be reduced by one-fourth. As you make coal cheaper, you expand its use. As a matter of fact, although coal is still wasted grievously, even by the best appliances in use, economy of coal has proceeded in some measure during the last fifty years, and increased consumption has accompanied greater economy. It is difficult to say what balance would be arrived at with a greatly increased economy; and only experience can show at what point economy of use would more than counterbalance the stimulation of demand created by economy of use. If we imagine coal turned into electric current, and distributed at as low a figure as one-eighth of a penny per unit, the present mechanical work done in the United Kingdom could be accomplished with only 60,000,000 tons instead of the 150,000,000 tons now used; and upon such a consumption as this it is apparent there

MAINTAINING THE BALANCE OF TRADE

RAILWAY SIDINGS AT HULL WITH COAL WAITING FOR TRANS-SHIPMENT ABROAD

ENGLISH COAL STACKED AT MARSEILLES FOR USE ON THE FRENCH RAILWAYS

would be such a saving of our chief asset that the exhaustion of our best supplies would be postponed for a very long period indeed.

But as soon as electric current fell to such a price, a hundred fresh uses would be found for it because of its cheapness. Every household would employ it, and every manufacturing industry would be so enormously stimulated that we should certainly use more power than before the improvement in economy was effected. We cannot therefore see our way very clearly in this direction. Nevertheless, coal conservation remains a primary national duty, since, as we must use our coal or perish, it is obvious that we should make the most intelligent use of our power supplies; and we are entitled to hope that conservation and economy of use, in spite of their stimulation of demand, would prolong the lifetime of the coal which gives us our relative advantage.

The Economy of the United Kingdom Dependent on the Use of Coal

As to the dethronement of coal by other sources of power, we are at the mercy of fortune. We know that if a scientist to-morrow overthrew coal and made it obsolete, he would in doing so overthrow the major part of the economy of the United Kingdom. He would deal us a blow more severe than could be inflicted by any possible defeat in war. We should suddenly find ourselves in the position of Spain or Italy, or Holland or Sweden, or worse, for we should be without the water-power which is possessed by some of these nations, and the suddenness of the shock would be such as to cause a degree of misery and distress in our teeming towns which even rapid emigration on a large scale could not alleviate. We can only say that at present there is no sign of a scientific production of power cheaper than that which can so easily be derived from accessible coal, and that while easily accessible coal lasts there may be no cheaper source of power.

A great deal has been said with regard to the supplanting of coal by oil, and we have even seen British writers rejoicing at the prospect of it as mitigating our dependence upon coal. Here, again, we have an exhibition of complete misunderstanding of the British economy. If ever oil displaces coal, so much the worse for us. We have no mineral oil; and if there were enough mineral oil in the world to displace coal, we should lose that relative advantage which we possess as long as coal is the ruling power. It is true that we might import mineral oil, but, if we could, so could other nations, and our relation to it would be one of natural disadvantage, and not natural advantage. Mineral oil is, of course, merely a natural distillation from coal, and the true way to regard mineral oil is to consider it as one with coal. Those nations which have it—and we are not one of them—have in effect an additional supply of coal in a very convenient form.

The Use of Oil Fuel Probably Harmful to British Commerce

It is possible artificially to distil oil from coal; and in so far as that can be economically effected it leaves the power problem just where it is, for if we use oil made from coal we use coal.

There is a third way of obtaining oil for oil engines, and that is to get it from the vegetable world; and it is possible that the increased use of internal combustion engines using oil for fuel might greatly stimulate the extraction of oil from vegetable substances. If that proved to be the case, we should again be at a relative disadvantage, since, obviously, the United Kingdom is one of the least fitted countries in the world to have a large native vegetable oil production.

In this connection it is quite possible that oil will come to supplant coal in marine engineering. If so, our coal exports may be largely diminished by this cause, unless it proves to be economically possible to use oil artificially distilled from coal. It seems improbable that artificial oil could compete with natural oil for this purpose, however; and here we may have a cause in the near future of some diminution in British coal exports (which we have already seen to be made chiefly for navigation purposes), with consequent reaction upon our shipping and commerce.

Nothing Certain About the Future of Coal Except Its Uncertainty

To go no further, it will be seen that nothing is certain about the future of coal—the future of power—except its uncertainty. It is a matter in which it is simply impossible to make an intelligent forecast, especially in view of the rapid march of scientific attainment. Given the continued use of coal and supremacy of coal power, and we can prophesy the future as accurately as Jevons, in 1865, prophesied the future supremacy of the United States in the iron and steel trade. It is because we do not know how long coal will be useful that we find ourselves gravelled in any attempt to make an intelligent estimation of the future progress of our country.

THE NATIONS WHICH SELL COAL—COMPARATIVE FIGURES FOR 25 YEARS

Exports of Coal (including Bunker Coal)	1886	1890	1900	1910
	Tons	Tons	Tons	Tons
United Kingdom	30,400,000	28,700,000	58,400,000	84,500,000
Germany	9,700,000	19,800,000	19,200,000	32,400,000
United States	1,200,000	1,900,000	7,900,000	15,400,000
France	600,000	800,000	1,200,000	1,600,000
Belgium	5,700,000	6,500,000	7,500,000	7,100,000
Austria-Hungary	600,000	600,000	1,200,000	1,100,000
British India	100,000	200,000	500,000	900,000
Australia	800,000	800,000	1,700,000	2,800,000
Canada	400,000	600,000	1,500,000	2,100,000
Union of South Africa	—	100,000	300,000	1,300,000
Japan	700,000	1,200,000	3,400,000	2,800,000

The reader will not be surprised that, in view of all the considerations which we have set out, every intelligent student of the subject has arrived at the same conclusion with regard to British coal exportation—that it would be folly to restrict the outward shipment of fuel, and so to inflict an immediate severe blow upon our economy.

This view is held not only in the United Kingdom, but elsewhere. The other two great coal nations, Germany and the United States, have done all that they possibly could to increase their coal exportation, and the German Empire is now exporting almost as much coal as the United Kingdom did twenty years ago.

In the table above will be found an account of the coal exports of the chief countries which sell coal.

The United Kingdom exports more coal than all the other nations of the world put together. But Germany is a fair second, and is doing all that she can to increase her sales. The facts in this table, however, should not be considered without reference to the importations of coal by the same countries, otherwise a false view of the subject is obtained.

We therefore add the table below relating to the excess of imports or excess of exports, as the case may be, of the same countries for the year 1910, together with some other countries which do not figure at all in the export list.

The United Kingdom has, of course, no coal imports of any importance, and the figure representing her excess of exports of coal is therefore nearly 85,000,000 tons.

With regard to Germany, the Empire is both an importer and exporter of coal, but on balance she is an exporter. This will be easily understood. Coal from Germany can be economically exported to the Mediterranean, for example. It is also true that it is economic for Germany to import coal into Hamburg from the United Kingdom.

COAL IMPORTS AND EXPORTS FOR THE CHIEF COUNTRIES IN 1910

(Including Bunker Coal)

Country	Exports from	Imports into	Excess of Exports	Excess of Imports
	Tons	Tons	Tons	Tons
United Kingdom	84,500,000	—	84,500,000	—
Germany	32,400,000	12,200,000	20,200,000	—
United States of America	15,300,000	2,200,000	13,100,000	—
France	1,700,000	19,300,000	—	17,600,000
Belgium	7,100,000	7,400,000	—	300,000
Austria-Hungary	1,100,000	10,900,000	—	9,800,000
Italy	—	9,200,000	—	9,200,000
Spain	—	2,500,000	—	2,500,000
Russia	100,000	4,900,000	—	4,800,000
Sweden	—	4,600,000	—	4,600,000
India	900,000	300,000	600,000	—
Canada	2,100,000	10,000,000		7,900,000
Australia	2,800,000	300,000	2,500,000	—
New Zealand	300,000	200,000	100,000	—
South Africa	1,300,000	100,000	1,200,000	—
Japan	2,800,000	200,000	2,600,000	—

The United States has a considerable export balance, which is likely to grow largely. France has a very large balance of coal imports, and the same is true of Austria. After Austria, Italy is the leading importer of coal, which she chiefly obtains from the United Kingdom.

Looking at the record as a whole, we see that it is largely governed by the economic range of possible coal exportation. The United Kingdom cannot, of course, export coal economically to Japan, and we see Japan figuring in the table as an exporter, for she has a considerable economic range in Eastern markets. Other exporters of coal are India, Australia, New Zealand, and South Africa.

From what has already been said, it will be understood what a large part cost of transport plays in the commerce of coal. In the last generation there has been a curious reaction upon coal exportation by the reduction in freights caused by the use of coal itself. The substitution of the steamship for the sailing-ship caused a complete change in the conditions of sea-carriage; and although precise figures are not available, there is no doubt that there has been an enormous fall in sea freights in the last thirty or forty years. If we go back to the period before the steamship had replaced the sailing-ship we find that it cost over £1 a ton to take coal from a British port to Egypt. Mr. D. A. Thomas gives the following facts with regard to the price of coal exports, and the cost of freighting coal from Cardiff to Port Said.

EFFECT OF THE FALL OF FREIGHTS UPON COAL EXPORTS

Average of Years	Average Price of Coal Exported	Average Coal Freight from Cardiff to Port Said	Coal plus Freight at Port Said
	Per Ton s. d.	Per Ton s. d.	Per Ton s. d.
1866–1870	9 9	22 6	32 3
1871–1875	16 0	18 8	34 8
1876–1880	9 6	14 7	24 1
1881–1885	9 0	12 4	21 4
1886–1890	9 6	9 9	19 3
1891–1895	10 6	6 0	16 6
1896–1900	10 9	9 2	19 11

The price of coal exported, save for the abnormal period 1871-1875 (when there was a coal famine caused by the extraordinary trade conditions which followed the termination of the Franco-German War), has remained fairly constant, but the freights have tumbled down with the progress of steam navigation. *So we have coal itself reducing the cost of navigation, and thereby making it easier for Egypt to get British coal.* It will be seen that in 1866-1870 a ton of coal landed at Port Said was worth 32s. 3d., whereas in 1896-1900, although coal in the interim had advanced by one shilling a ton, it was worth at Port Said only £1.

In this connection it may be usefully observed that the effect of a freight is exactly the same as the effect of an import duty, and that the fall in freights of the last thirty or forty years has meant for the world at large *the equivalent of a tremendous reduction of the world's tariffs.* This will be clear from the following illustration. Suppose that in a given period a certain nation raises the import duty on wheat by, say, five shillings per quarter, and suppose also that in the same time the freight on wheat to the ports of the country falls by five shillings a quarter, the net result is that the fall in freights cancels the increase in duty. This has actually occurred in practice, as will be gathered from the above table. Even while Germany and other countries were increasing their import duties, freights were falling and wholly or partially obliterating the effect of the rise in duty.

The fact that sea carriage is so much cheaper than land carriage, especially when railway rates are as high as they are in the United Kingdom, makes it possible for Egypt sometimes to obtain the use of British coal on better terms than some people can obtain it in the United Kingdom itself; and that is a fact which ought to be carefully borne in mind by those who have at heart the welfare of the country. For example, it has often been possible for the Egyptian railways to fire their locomotives with British coal more cheaply than can be accomplished by the London and Brighton Railway, which has to import its coal overland from the coal centres of the United Kingdom.

The high British railway rates, indeed, may be said to obliterate part of the natural advantage which the United Kingdom possesses in her great coal supply; for if English coal can be taken to Genoa as cheaply as it can be taken to London, then an Italian manufacturer is able to use British coal to as much advantage as a London manufacturer. This consideration has to be taken into account as modifying the fact we have already insisted upon: that

it is impossible to carry on competitive manufacturing industry on imported coal. If London consents to the existence of such railway rates as put her at the same economic disadvantage as though she were built in a land which possessed no coal of her own, then, of course, the favourable natural economic factor is modified by the unfavourable and unfortunate artificial economic factor.

Our Increasing Competition with Germany in the Coal Markets of Europe

In view of the important part played by coal exports, how are we likely to be affected by the competition of other coal exports? From the facts already given, it will be seen that competition exists. It takes two forms. The first is the development in any particular market of native coal, or other power resources. The second is the export competition of countries which, like ourselves, are able to produce a surplus of coal over and above their own requirements.

In the Mediterranean, we find a country like Italy not only importing coal, but developing water-power in order to make her increasingly independent of coal. So far, in spite of the great increase in water-power plants in the Peninsula, the increasing importation of coal has not been checked. In 1886, Italy imported less than three million tons of coal, whereas she is now importing over nine million tons. In the Mediterranean generally we have to compete with the coal of Germany and the United States, but it is unlikely that the United States competition will seriously threaten until she places her shipping on an economic basis. Another important market is the North of Europe, including Holland and Belgium, Scandinavia, German, Swedish, and Russian ports. These are great markets for the coal of Northumberland, Durham, and Scotland, and in them there is an increasing competition with Germany.

Where we are Likely to Meet Keener Competition with Japan and America

The rich lands of South America also buy a great deal of British coal, but it is to be expected that American coal will be able to compete there with much more success in the future, after the opening of the Panama Canal, and the great stimulation of American shipping and commerce which will follow. Australia is a growing competitor in South America, as is also British Columbia. The African markets are of less importance, and the figures already given will show that native coal is increasingly a local competitor in South Africa.

India was at one time a coal market of some importance, but, as we saw in Chapter 4, India has very good coal of her own, and she now exports more coal than she imports. India sends her coal to Ceylon and to Singapore. Beyond Singapore, Japan becomes a competitor, and in 1910 Japan exported on balance 2,600,000 tons of coal. Obviously, it is more economic for Hong Kong to get coal from Japan than from the United Kingdom.

As for the United States, the West Indies, and Central America, American coal is, of course, on the spot, and we cannot reasonably expect to compete with it.

Generally, given the increasing expansion of trade in the world at large, it is likely to cause in the aggregate as large a continued demand for British coal exports as we can reasonably meet; and while coal remains enthroned we are not likely to lose our coal market in the aggregate. If any further increase occurs, it is more likely to take place in the European markets than in other parts of the world.

The Lessons to be Learnt from the History of the British Coal Trade in 1912

We are removed but about a century and a half, or, say, five generations, from a period when British coal began to be put seriously to economic use and to work a marvellous change in the national position and prospects. In a much shorter period it is possible for a nation to forget the cause of such a change, and to imperil its future by sheer neglect of the mainspring of its power.

In 1912, Britain has presented a spectacle which may be truly compared to a man deliberately stopping the action of his own heart. It would be impossible for that to occur in a nation which thoroughly understood the all-important facts which have been discussed at length in the present and foregoing chapters of this treatise.

We cannot control scientific development in such fashion as to ensure that for all time the United Kingdom shall possess a great relative advantage in respect of natural resources. We can at least make sure, if we care to do so, of using the resources we have to the best economic advantage. A well-informed people would assuredly see to it that its governing powers did not fail in this all-important particular; and the experiences and revelations of 1912 show the supreme necessity for the wide dissemination of such information as it is the peculiar province of this publication to afford.

WHAT SHALL AVAIL IF FREEDOM FAIL?

The noble Statue of Liberty at the entrance to New York harbour, designed by M. Auguste Bartholdi and presented by the French nation to the American Republic in the year 1886, is the largest statue in the world. It was ten years building, cost £120,000, and stands over 305 feet high from the base of the pedestal to the torch. The figure itself is 151 feet high.

THE RELIGION OF LIBERTY

The Power Behind the Marvellous Development of the Anglo-Celtic Races

HOW FREEDOM IS BORN OF LAW AND ORDER

Under a certain system of society a few millions of one of the most self-contained of Western peoples have in less than three centuries become a fourth of the white population of the world; and about five-twelfths of the human race have passed under the direct influence of their government, laws, and institutions. Five millions of men, women, and children, inspired by the religion of liberty, have now grown into a mass of states and dependencies, with a population of about 530 millions.

This tremendous achievement has had a deep and widespread effect on all the civilised nations of the earth. Practically every advanced race has profoundly felt the influence of either the monarchical or the republican movement of liberty that developed among the Anglo-Celtic peoples; and for the last two hundred and fifty years political thinkers have been busy explaining the principles of modern liberty.

Now, there are two ways of discussing an important idea. One can start by laying down and defining certain elementary truths, and then go on to draw out a theory of the whole matter. This is the deductive method. The other way is to begin by collecting all the facts bearing on the problem, and then see what general idea can be obtained from the study of these facts. This is the inductive method, which, since it was established by Bacon, has been usually adopted by men of science. It is far more difficult to find how liberty has originated and is maintained than to talk about the theory of liberty. The greatest of modern historians, Lord Acton, spent his life in collecting materials for the inductive study of liberty, but died before he could master his subject sufficiently to write about it. Yet we must attempt some selection from the vast amount of facts available before we can hope to arrive at a valid notion of the nature of the greatest event in the history of human societies.

Theoretically, liberty seems easy of achievement, but actually it is the supreme flower of social organisation. No doubt, there have been many free peoples in the long history of the human race. It is possible that some of the earliest groups of mankind formed free associations. We still find scattered families of low savages which are not held together by any political organisation. But theirs is not the kind of liberty that has become the grand social force of the modern world. It is mere anarchy; and the races that practise it have been driven by their weakness into the least valuable parts of the earth. Freedom to live one's own life wildly as one will, exempt from any sort of control, is a thing of no importance from a social point of view. True liberty is something very different. It comes only at the end of hundreds of thousands of years of social development. Mankind had to be educated by very despotic methods before it acquired the habits of co-operation which enabled it to dispense with some of the machinery of coercive government.

Thus it may fairly be said that ancient despotism is the foundation of modern liberty. Man had to be hammered into an obedient, law-abiding, self-sacrificing, social unit; and his nature was so hard and selfish and wilful that the process of transforming him into a possible freeman has taken a million years. Such, at least, is our view of the matter. And this view seems to us to give meaning and purpose to the otherwise blind, mad wars and miseries and tyrannies of every kind through which mankind has passed.

Undoubtedly some part of the sufferings of the human race has been produced by non-human causes—by famine, wild beasts,

diseases, over-population, earthquakes, and other natural disasters. But, on the whole, the things that men have done to men have probably caused more mental and bodily pain than has been produced by all the accidents that we may loosely term of natural origin. If from the beginning man had only had to contend with the difficulties of his surroundings, he would have been spared the blood and tears he has shed in his struggle for a world-wide civilisation and a world-wide peace.

The Large Part Played by Man's Inhumanity to Man

We have never been able to agree with the lines that Dr. Johnson inserted in Goldsmith's "Traveller":

"In every government, though terrors reign,
Though tyrant kings or tyrant laws restrain,
How small, of all that human hearts endure,
That part which laws or kings can cause or cure!"

For it seems to us that in ancient times liberty was as little to be found in "that bliss which only centres in the mind" as it was in the external circumstances of life. For, as we have seen in tracing the origin of leadership in primitive ages, the superstitions and customs that moulded the souls and minds of men were but an instrument used by cunning and ambitious wizards, greedy for power of the most despotic kind. In order to compel the free savage to co-operate with his fellow-men, his leaders robbed him of practically every sort of initiative—moral, intellectual, and political. He became something very little better than a social automaton. And so long as his superiors did not deprive him of food, he was generally willing to obey them.

The Early Civilisations Based on Intense Social, Religious, and Intellectual Constraint

When we find that some of the lowest and least organised of savages have an idea of a Divine All-Father, and that this idea cannot be found in the earliest beliefs of any of the advanced races, it seems possible that the religious instinct of mankind was perverted in order to promote the subordination of the individual. The idea of a Divine Father was gradually obscured by magical practices and tribal idolatries that left to the greater part of mankind no spiritual loophole through which their souls could escape from the power of the chief and the wizard. In early times liberty of mind was even a rarer thing than liberty of action. The entire forces of human nature were directed to the work of compelling mankind to learn the necessary habits of co-operation.

Thus it was on a basis of religious, intellectual, and social constraint that the earliest civilisations of which we have any record were founded, in Babylonia, Egypt, and Crete. None of these, at the widest estimate, carries us back much farther than eight thousand years. It is worthy of remark that the wizard chiefs of certain Mongolian tribes were the first known men to lead mankind to a settled and stable form of civilisation. They were despots wielding both spiritual and political power; and by drilling their people in co-operative labours they built up a series of little agricultural and industrial states at the head of the Persian Gulf. Here somewhat of the true spirit of liberty was able to reveal itself when the communities began to develop their wealth and industries. The position of women was high, and they were able to form themselves, when unmarried, into large co-operative societies, the members of which were free mistresses of their time and labour. Even slaves were allowed to save and hold property and purchase their freedom.

Peaceful Workers in Early Days Overborne by Military Strength

Unhappily, these peaceful groups of hard-working farmers and ingenious artisans seem to have been lacking in military strength. Their personal freedom was purchased at too high a price, and the result was they were conquered by barbaric invaders from the Arabian desert, who retained the more coercive form of government and imposed this on the conquered city peoples. Thus arose the great Babylonian Empire, which, in its later development in its Assyrian colony, produced one of the most terrible despotisms known in history.

The fact is that the early essays in freedom undertaken by small industrial societies were of little practical importance. The surrounding nations were unfitted for free institutions, and they were able to build themselves into great and powerful states only by stern and rigorous tyrannies. No gentler means of compelling social co-operation was practical on a large scale; and yet nation-building on a large scale was absolutely necessary in order to resist the armies of hungry barbarians that kept sweeping down, now from the mountains and now

from the deserts, on the young civilisations growing up by the great rivers.

On the whole, priestly government in these ancient times seems to have been more favourable to liberty than was the rule of the great kings. Of course, there were many cases where the priests of idolatrous races were among the chief obstacles to social advance. Jealous of any progress of thought that would strip them of the power they had won over the popular mind by magical practices and superstitious rites, they fought savagely and bitterly against every movement of enlightenment. This happened in Egypt and also in ancient India, where the nobles seem to have started and carried on one of the most splendid advances in thought that man has ever engineered.

The Lasting Debt of the World to the Hebrew Race

Yet there was one priestly caste that was open to the new influences that began to stir in the soul of man four thousand, or three thousand five hundred, years ago. How much the civilised world of the present day owes to the leaders of Israel, who recovered the idea of a Divine Father and made that idea the great moral inspiration of the government of their people, can scarcely be estimated. It was they who lighted the torch of liberty, and gave to the later and vaguer notion of the brotherhood of man the religious force necessary to make it an eternal principle of human government.

It is true that the Israelites themselves never carried to its full conclusion the ennobling idea from which they derived all their strength. They often fell away from the high standard of life that their prophets set before them. They allowed some of their kings to grow almost as tyrannical as an Assyrian despot; and it was very late before they produced, in Isaiah, a man of far-piercing spiritual genius, who had a vision of all the peoples of the earth living in unity and freedom under the guidance of a Divine power, before whom the serf was equal to the king, and the orphan level with the mightiest conqueror.

Hebrew, Roman, and Greek Influences on Mankind Compared

With all their faults, the barbaric desert tribes that descended on the fruitful land of Canaan, and put to death the inhabitants of many of the cities they conquered, were the greatest of all races. There was that in their character which made them more valuable to mankind than the brilliant Greek and the energetic Roman. The Israelite no doubt lacked the versatility of mind which enabled the Greek to lay the intellectual foundations of the modern world; but he had a passionate interest in all matters relating to the actual conduct of human life, which enabled him to drive, like a spearhead, through all the fabrics of ancient civilisation, and touch the ultimate realities of human existence. Placed between the priest and the prophet, he did what no common person had ever before done. He sided with the prophet, and thus prevented the grand force in his religion from being restricted and checked and practically wasted as were the new forces in Brahmanism, Buddhism, and various Oriental mysticisms.

It was the Israelite who carried out the grand reformation of thought that freed mankind from the chains of primitive superstition. His work was not confined in its effect to some narrow class of enlightened nobles as in India, or to some restricted circle of aristocratic thinkers as in Greece. The movement of mind among the Hebrews was a popular movement. It began with an appeal to the people, above the heads of priest and king, and it produced a profound and lasting effect on the popular conscience.

The Hebrew Evolution of the Gospel of the Brotherhood of Man

The priests themselves were compelled to follow the new movement; and credit must be given to them for collecting and preserving those records of the spiritual evolution of their race which now form the first part of that sacred book which has profoundly affected the destinies of all the most advanced races of the modern world. When the priesthood had apparently done all that was necessary to save for the Jewish nation its treasures of the spirit, the popular mind still went on developing in its own way the ideas of the prophets. And at last the gospel of the brotherhood of man was freed from its Hebraic husk among the peasants and fishermen of Galilee, and expressed in a universal form in the Sermon on the Mount.

It was then that the spirit of true liberty first began to work strongly in the minds of men. Nothing was evolved in Greece or Rome, in their most democratic periods, comparable for one moment to the enfranchising power of Christianity.

There is a great deal of misconception still current in regard to the advances in free government made by the Greeks and the Romans of the republican ages. Our poets—Shelley and Swinburne in particular—have created a misleading confusion of

thought in the matter. For though Shelley has sung

"Let there be light! said Liberty,
And, like sunrise from the sea,
Athens arose! Around her born,
Shone like mountains in the morn,
Glorious states——"

practically every form of Greek government was founded on slavery. There were often five slaves to every freeman. An aristocracy of various degrees, enjoying among themselves certain free institutions, was all that Greece produced. Moreover, it must be remarked that both the Greek and the Roman were, as a rule, severely restricted by State religions that controlled all their activities. They were as much bound by custom and superstition as the savage is; and the movement of liberal thought, faintly discerned in the poems of Homer and fully revealed in the sayings of Socrates, did not affect the people at large. Their minds were still ruled by superstitious feelings and customs when St. Paul came to Athens; for the breaches made in their beliefs by their great thinkers had merely opened the way for still lower forms of unreason. The entire fabric of Græco-Roman civilisation was hardening into a pure despotism in the reign of the Emperor Diocletian, when Christianity was becoming a force of general scope.

ST. FRANCIS OF ASSISI
From the statue by Luca della Robbia

So it does not look as though Greek thought of the creative age was able to produce by itself any large and lasting enfranchisement of the people. Rome, too, was not a liberator of mankind. What Rome really did was to consolidate every means of government control, and reduce all the races of the old world to habits of obedience and social co-operation. And, having done this, Rome rewarded its subjects with a system of just and well-thought-out laws, in which for the first time in human history the idea of universal justice was made fairly effective in practice. A despotism with an admirable bureaucracy and an admirable code of laws was all that the modern political world directly inherited from Græco-Roman civilisation. There was also a widespread web of trade guilds, in which the ancient idea of free association for industrial purposes was developed; and there were a few costly books, in which the discontents and vain ambitions of the fallen aristocracy were artfully disguised and put forward as pure and disinterested aspirations for popular liberty.

How much inferior in enfranchising power Græco-Roman civilisation was to the religion of Divine brotherhood that spread from Palestine can be easily measured. We have only to estimate what the new religion lost when it at last came to terms with the Roman world and the Roman emperors. In its struggle with Oriental mysticism and superstitious rites, Christianity was for a time almost emptied of its liberalising force, and it became merely another brilliant State religion that served to keep the people quiet and united and thus smoothed the work of Imperial administration.

As such it appealed to Constantine. And when Charlemagne built up his empire on the ruins of the Roman world, he also was attracted merely by the consolidating function of the new creed. It was useful in destroying the old tribal beliefs that kept alive the spirit of independence. So the pagan Saxons were offered the alternative of being baptised or being put to death. What the barbaric monarchs wanted in their new territories was a uniformity of thought, custom, and worship on which a stable form of coercive government could be erected. The political structure of Christendom was built on a military foundation; and it only needed contact with the Saracens of the South of France to quicken the evolution of the feudal system.

It is clear that there is no room for the growth of free institutions in a stern and effective system of feudalism. Yet an

influential school of writers wishes us to believe that our Celtic or Teutonic ancestors were noble savages with traditions of liberty which they brought, a priceless gift, to the civilised world that they destroyed. We are told that we must not look to the slave-driving Greek and Roman for the germs of modern freedom, but to the white Zulus of the German forest, the Baltic Sea, and the British Isles, with their human sacrifices, serf population, and oppressed tribesmen, their tyrannical nobility and domineering chiefs and kings. But, as a matter of fact, there was as much real liberty of mind and action among our barbaric forefathers as there was in Zululand a hundred years ago. The political organisation of the European barbarians was naturally looser than that of the Roman Empire. So there was space for new developments. But instead of maintaining any spirit of freedom, the Teutonic traditions ended in a system of military tenure of land which had to be broken down before modern civilisation became possible.

In the meantime, the Christian Church became the ark in which civilisation was carried for five centuries across the sea of barbarism: and, resuming the ancient Hebrew traditions, the priesthood tried to establish a theocracy. This led to a long conflict between the Papacy and the feudal rulers; and it was then that the seed of liberty sown by their religion in the minds of the common people began to germinate and scatteringly take root and flower. In certain Italian cities, where the trade guilds of ancient Rome had survived the shock and anarchy of the Dark Ages, a new kind of republicanism appeared. It was often modelled on the Roman commonwealth, but instead of being aristocratic it was middle-class. The feudal nobility were often driven out of the city by the merchants, and—this is one of the new things—there was no slave labour. Sometimes when the rule of the burgher classes grew oppressive, the ordinary working people were able to win political power, and establish a veritable democracy.

Mainly by reason of the power of the free towns, a revolution of tremendous importance was brought about in monarchical government. When a king wanted to raise money he had to call to his council the representatives of the towns. First, the primitive council of chiefs was developed into the "royal court," at which assembled the immediate vassals of the monarch; and then, as the strength of the townspeople increased, they won a place in Parliament. Thus the feudal struggle between monarchy and oligarchy was transformed by a new element which partly aided and partly controlled the actions of both the kings and the nobles. England, as is well known, took her Parliament from a Continental model. It was a French leader of the English nobility who first summoned the representatives of our cities in 1263. The monarchy founded by the Normans was too strong for the nobles to fight alone. So began the alliance between the barons and burghers of England which ended in establishing in the fourteenth century the weighty principle that new taxation is illegal without the consent of Parliament.


ISAIAH, POET-PROPHET OF ISRAEL
From the painting by Bartolommeo in the Uffizi Gallery, Florence.

In France, free institutions were destroyed through the nobility coming to terms with the king and obtaining privileges at the expense of the people. In Italy, there was no central controlling force against which to contend, and the free cities took to fighting each other, and fell into the hands of tyrants or oligarchs. England, one of the most backward of nations in developing free institutions, was benefited by the exceptional strength of her monarchy. Centuries of rigorous administration under Norman rule had made the English people wonderfully law-abiding and patient. Even the nobles were strongly controlled, and

made the most obedient of military aristocracies.

Lords and commons were alike drilled to social conformity and social co-operation; they enjoyed the advantages of a vigorous administration without its disadvantages. That is to say, their powers of initiative were increased rather than repressed in their struggle against the centralising power. Moreover, the true, liberalising spirit of the Christianity of Christ had been revived by St. Francis of Assisi; and the followers of this great mediaeval prophet spread through England, preaching wildly and passionately the new gospel of democracy. Some of them were behind the risings of the English peasantry, and probably wrote the revolutionary portions of "Piers Plowman."

There have no doubt been many peoples as law-abiding and orderly as the English nation; but it is doubtful if any other race has been equally well drilled in all fields of social conformity, and at the same time possessed of so high and living a power of personal initiative. The Norman forced his subject nation to keep his laws, but he was unable to deprive the vanquished Englishman of his liberty of mind. The Church, too, was a refuge in those troublous times to men of independent character; and credit must also be given to the obscure army of lawyers who maintained the traditions of English common law against the revived influence of Roman law and the continual pressure of canon law. For room was thus left open for the evolution of that bulwark of English liberties—trial by jury.

Here, again, the extraordinary law-abidingness and social conformity of the English people enabled them to escape from the Continental course of social evolution. The English of the early middle ages were as true to their Church as they were to their king. They never fell into any of the strange and unchristian forms of belief that spread from the East, and threatened to wipe out of the human mind the image of Christ. Therefore there was no reason to establish in England that early form of Inquisition which all the other Governments of Europe gradually adopted for use in criminal trials of every kind. Even at the present day, a French or German magistrate is somewhat of an Inquisitor, though there may be a jury, formed on the English model and empowered to decide the case.

THE BARONS DEMANDING CONSTITUTIONAL PRIVILEGES FROM HENRY III. OF ENGLAND

In the old days, Continental judges always regarded a prisoner as guilty until he was proved to be innocent; and instead of allowing him to be judged by his peers, they tortured him with dreadful machines to compel him to confess. It was the only method of criminal trial with which they were acquainted, and it was consonant with the traditions of Roman law. The horrors of the Spanish Inquisition can be matched by comparatively modern cases of criminal trial in Europe. Victor Hugo has a tragic poem on the matter in his "Legends of the Ages," in which he attacks with righteous anger the most famous judges of ancient France. Bodin, the first modern political thinker, was one of those who, as Hugo says, used on many an innocent prisoner "red-hot iron and Roman law."

Jean Bodin was the author of "De Republica," which was published in 157?, and formed the starting-point of modern political thought. It is usual for writers on the theory of liberty to begin with him; w

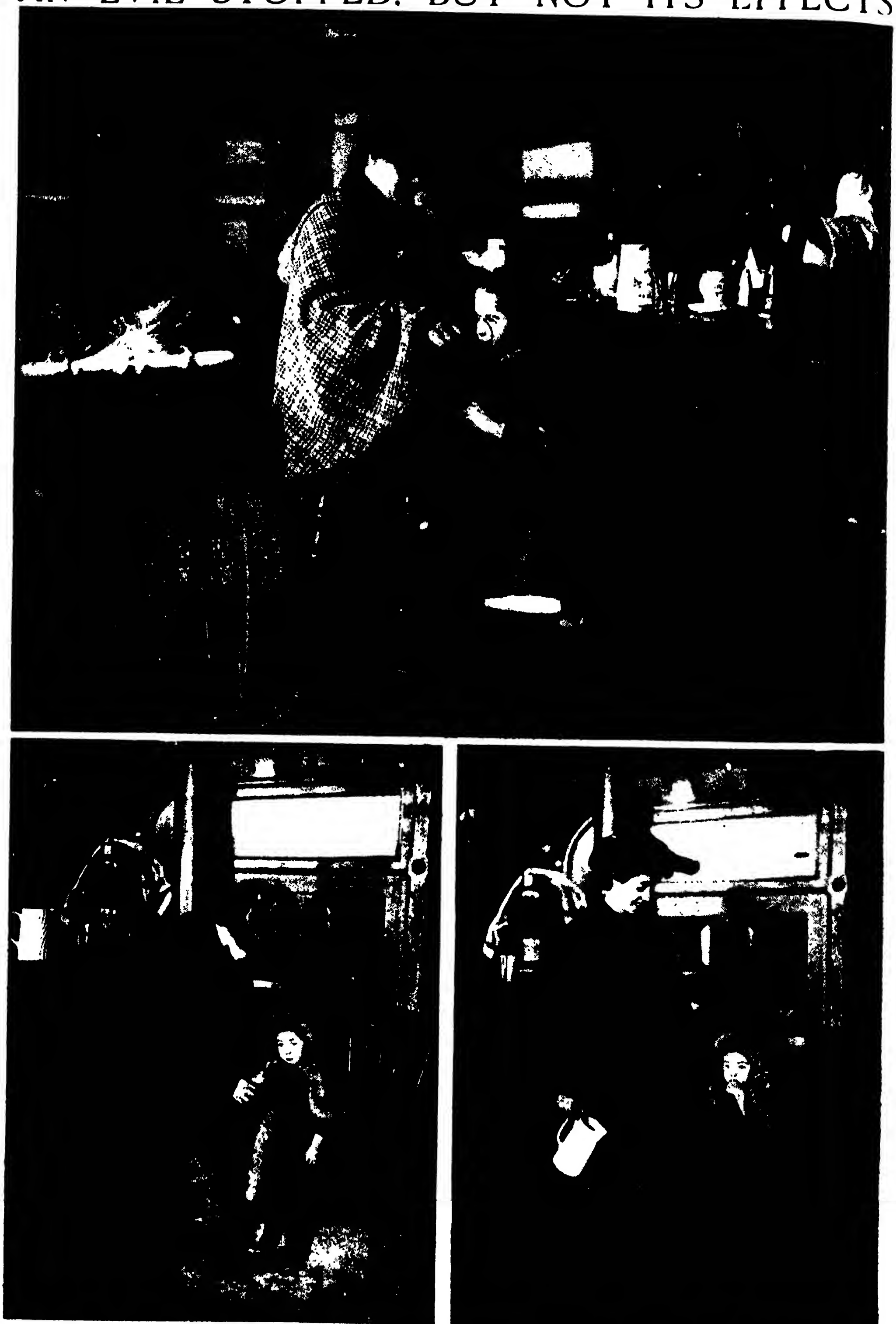
prefer to introduce his name at the close of our brief survey of the actual facts. For he seems to show that real liberty is not to be won by merely thinking about it and trying to define the scope and limits of monarchy or democracy. Liberty is a living balance between the need for State control and the need for personal initiative. Its effectual exercise does not depend upon the right definition of any set of ideas, for it is the defect of ideas that men often let them rest in the understanding and do not make them a constant and effective rule of conduct. Everyone would admit the reasonableness of the principle of doing to others what you would they should do unto you, but not until human nature is much changed for the better will the entire fabric of civilisation be really affected by the universal practice of this principle. The historic enfranchisement of the individual member of the most progressive races has not been won by theory, but by building up habits of co-operation and social conformity, and then advancing towards the free use of individual initiative within the limits marked by national traditions.

In the last hundred years many of the peoples of the earth have copied some of the political and legal institutions on which the liberty of the Anglo-Saxon races is based. The theories on which the other peoples have worked have been drawn up after long study by the best of their political thinkers, but in scarcely any case has the ordinary member of these foreign societies succeeded in obtaining that balance between law and order and personal initiative which still happily distinguishes our Constitution. Sometimes the power of the central Government has been made too large, sometimes the freedom of the individual has been so great as to provoke a counter-movement towards tyranny or oligarchy.

If ever our people generally lose their extraordinary law-abidingness in the struggle for some other popular advantage, they will purchase that advantage at the loss of their real liberty. A great deal can be done more thoroughly and quickly by a coercive Government than can be effected by a race of free men. Too much State control, however, dries up the source of progress. By checking the immeasurable and infinitely varied force of personal initiative in a large and populous civilisation, State control puts an end to the continual experiments from which progress is derived. Jean Bodin was certainly a great political thinker, but we doubt if a hundred Jean Bodins would ever have elaborated the system of justice which has developed, by free experiments, out of the English method of trial by jury. Liberty exceeds all theory, for it contains the future as well as the past and the present. Its forms will vary with all the progressive changes of human society. It cannot fully be justified by the science of life, for it is less a science than a religion. It supposes the brotherhood of man, and, in ultimate analysis, a Divine Power, to whom the human spirit is allied.

TRIAL BY JURY IN THE DAYS OF KING ALFRED, BY C. W. COPE, R.A.

AN EVIL STOPPED, BUT NOT ITS EFFECTS



The taking of young children into public-houses is now prevented by law, but the ill-effects of the practice will persist as long as a remnant is left of the generation reared in the public-house habit.

DARWINISM AND EUGENICS

The False Start of Darwinism Through Overstrained Assumptions and the Persistence of Disciples in Mistakes

EUGENICS BASED ON REAL HEREDITY

THE present chapter must be devoted to a repudiation of Darwinism as a foundation for eugenics, partly on grounds long stated by the present writer, and partly on the arguments put forward by the leader of modern genetics, Professor Bateson, in his Herbert Spencer lecture at Oxford, entitled "Biological Fact and the Structure of Society." Historically, the relation of Darwinism to eugenics is close, for Sir Francis Galton was a first cousin of Charles Darwin; and it was very largely "The Origin of Species" that set Galton thinking upon the problems and the significance of heredity in man. So long as all biologists, with very few exceptions, accepted Darwinism, plainly any proposals of eugenics had to be based, in part, thereon. And just at the present time we witness the curious but inevitable spectacle that, while the biologists are abandoning Darwinism, and while the authority of Darwin himself—who, it need hardly be said, was not a Darwinian—can be invoked against its extreme statements and the deductions therefrom, Eugenists as a whole are proclaiming Darwinism as the justification and warrant for a variety of proposals that must instantly be condemned if Darwinism be found wanting.

Darwin asserted the fundamental truth that species change and new forms are established less by the action of the environment in modifying them than by the *selection* of individuals of certain types for parenthood. Eugenics has thus been defined, by the writer, in past years, as primarily "the application to mankind of the Darwinian principle of selection for parenthood." But while that is certain, and the debt of eugenics to Darwin remains unquestionable, of course, we have to ask ourselves what kind of selection will effect the changes and the progress of type that we desire; and here we must be guided not by the best knowledge regarding heredity in Darwin's day, approximately half a century ago, but by the best knowledge of our own time.

It has been shown elsewhere in this work that the minute random "variations," round the mean or "average" of the species, which Darwin assumed to be inheritable, and upon which Professor Karl Pearson, for instance, bases his arguments for eugenic action, are now otherwise regarded by biologists. The true interpretation of them is all-important for eugenics. If they are "natural" or "genetic," inherent, germinal, then, according to the true grounds of modern heredity, they are liable to be transmitted, and are thus material for eugenic action, positive and negative. That was Darwin's belief; it was assumed by Galton when he framed his "law of ancestral inheritance"; and it is assumed by the school which Galton founded. But modern biology rejects it. These so-called variations are now known to be not natural or genetic at all. We call them fluctuations, and trace them to the slight random differences in nurture to which different individuals are exposed, especially during youth.

The reader will see, therefore, that this initial question is of incalculable importance. All the weight of argument and desire will be thrown in one scale by the Eugenists who regard fluctuations as genuine variations, as against those Eugenists, trained in biology, who regard them as nurtural, and therefore irrelevant from the point of view of selective breeding. It will be well, therefore, briefly to remind readers who do not closely follow the progress of biology that the modern view dates from as long ago as the year 1903, when Professor Johannsen of Copenhagen published his now celebrated

paper, "On Inheritance in Populations and in Pure Lines," in which he showed that "pure lines" can be isolated from populations, for instance of beans and barley, so that no amount of selection will alter their composition. They are all so similar, naturally, that it does not matter whether we choose the largest or the smallest to breed from. These differences are merely nutritive, and are not inherited. Ever since these experiments of Johannsen were confirmed and extended, the old ideas as to the power of selection have been obsolete. It used to be supposed that true variation was always going on, in all directions in all living creatures, and that sufficiently stringent selection, in any particular direction, could modify the race in that direction without limit. But we think differently now, though unfortunately most Eugenists are still preaching the older doctrine. The limitations of selection, as ordinarily practised, have long been familiar to practical men, in the case of plants and cattle and horses; and the results now being obtained in the breeding of such living forms are being based upon the abandonment of the old ideas, and upon the substitution of genetics, which begins by ascertaining what are true, inheritable variations and what are merely nutritive fluctuations. Eugenists must sooner or later come to realise the application of this radical discrimination to the supreme case of man.

The Greater Part of What Selection Selects Not Heritable

Thus, while we accept Darwin's idea of selection for parenthood as a primary condition for racial change, we are bound to reject the idea that that selection can be successfully practised on the naïve assumption, disproved by Johannsen nearly a decade ago, that practically all differences between individuals are really genetic. And we formally remind ourselves of the truth that, so far as Natural Eugenics is concerned, only those differences which we can prove to be genetic are our business. The reader may well guess how closely this principle touches the Eugenist when he comes to grips with individual cases; and the extreme difficulty, or impossibility, of making this indispensable distinction in a large number of cases will justify us in the very special attention which we shall devote to the cases, like the negative eugenics of the feeble-minded, where the evidence is conclusive and unchallengeable. It is largely, of course, on the foregoing grounds that modern biology rejects the Darwinian principle of natural selection as adequate to account for racial change. If we find that the greater part of the characteristics which natural selection will favour are not transmitted to the offspring of the favoured, the principle loses its efficiency to that extent. That, then, is the first of the chief grounds, three in number, why we here repudiate natural selection as a mode of achieving the eugenic aim; the greater part of what it can select is not inherited.

Natural Selection Produces Not Necessarily Progress, but Adaptation

The second reason for condemning natural selection and the survival of the fittest as a eugenic principle is one which is to be found in the nature of Darwin's own theory. No biologist can be named who assents to the pseudo-eugenic doctrine that anything which happens in a slum or a public-house is natural selection. The reader will frequently observe well-known names invoking that principle in this connection, but never the name of a biologist. The simple explanation is that the biologists know what the principle really is. The fact which Darwin had, if possible, to explain was the adaptation of living species to their environment. The school of "special creation" offered one explanation, and the new school of evolution had to offer some alternative. Darwin's was that the environment, which we may call "nature" in this connection, exercised a selection, accordingly called "natural selection," in favour of the best-adapted. Who shall be the best-adapted, and thus what the upshot of the process will be, entirely depends upon what the selecting environment is. The popular notion, among amateur Eugenists and especially among enemies of social reform and champions of class-prejudice, is that natural selection produces progress. Really it produces not progress, but adaptation, which is a very different thing. This adaptation may be progressive or degenerative; and the argument here adduced is that the kind of adaptation produced by so-called natural selection among men is, or would be, not progressive at all—which is what Eugenists desire—but in the direction of degeneracy.

The Eyeless Fish That are Naturally Selected for Blindness

Thus it is well known that, in the water of certain dark caves, there come to be produced a species of fishes that are eyeless. These blind fishes are described by Darwinism as a result of natural selection.

In the darkness the possession of eyes is a disadvantage, and thus, in time, the fishes that varied naturally and accidentally in the direction of "congenital" blindness would be selected, and the race would ultimately become blind. That is the Darwinian explanation of the facts—and a sufficiently fantastic one it is—but it will suffice for our present purpose, which is to show that those who quote natural selection as the hope of the human race do not even know what their own fetish means. Clearly the application to mankind of such parallels as that just quoted is easy enough. In that case circumstances have provided the fishes with a highly unusual environment where light is lacking; and the evident result (whether or not it be attained in the fashion the Darwinians suppose) is that the inhabitants lose the power to see. If the pit-ponies in our coal-mines were worked in absolute darkness, and bred there, it is more than probable that a race of blind ponies would thus be produced in similar fashion. But is that what we want in the case of man? To ask the question is to answer it, and with it to dispose of the ignorant assumption that natural selection exists in nature as a constant instrument of progress.

Man-made Abominations Such as Slums Not Natural, but Artificial

In so far as it exists at all, selection is only an instrument of adaptation; and so it was understood and invoked by Darwin, in order to explain the facts of adaptation. But, further, the process of selection which Darwin supposed and described was one of selection from and by *natural* environments—hence the name. Man had long practised artificial selection, producing certain results accordingly, and Darwin argued that Nature practises a natural selection by means of the various natural conditions which she provides. What happens in a slum or a public-house is therefore not natural selection, for the sufficient reason that a slum and a public-house are not natural. It is the grossest abuse of language and distortion of Darwin's teaching to use "natural selection" as the grotesque name for such man-made abominations as the slum and the gin-palace. We have already seen how notably the real and the artificial processes differ—natural selection slays *or* spares, the slum slays *and* spoils. But here the point is that the selective process effected by artificial things cannot be called natural selection.

Further, we have seen that the object, so to say, of natural selection is adaptation. That is what Darwinism supposes it to effect. The adaptation will thus, for nearly all living things, be an adaptation to light; hence eyes, and all that depends upon vision. However, once in a way, Nature behaves as man does when he builds a dark slum, and provides her fishes with a lightless habitation, whereupon they become blind. Now, we have to ask ourselves whether there is any need for us to breed a race which is adapted to the slum and the public-house. Once grant that these must exist, as certain facts of the natural environment must exist, and at once the argument must be granted. Though the process be terrible and long, we must breed a race that shall be able to survive under these influences, if we want a race at all.

Cruel and Unprogressive Uses of the Argument for Natural Selection

No escape offers from the proposition that we must be cruel to be kind, as Nature is supposed to have been during all the ages when she was adapting her living forms, by ruthless rejection of the less-adapted, to live in the natural environments which our planet affords.

Better, no doubt, even a slum-race (assuming such to be possible) than no race; and if the slum be part of "Nature," then there is nothing for it but "natural selection." The only other way would be to deal with the slums.

The same argument applies to every agency that is injurious to the race. On the theory of natural selection, as it is commonly misunderstood, there should be no regulation of traffic, nor limit to the speed and behaviour of motor-cars, nor penalties for injury they may cause; for plainly in this way we shall be able to divide the population, as has been wittily said, into the quick and the dead; and the valuable characteristic called agility will be developed among us and our descendants.

Why Improve Conditions at all if Natural Selection Under Disadvantages is Best?

No one would assent to such an argument, but many distinguished men are today using exactly similar arguments in favour of the slums, and the facilities for drinking, and against the abolition of disease. Yet which of them would relax the regulations against the sale of, say, cocaine, on the ground of natural selection? Would Dr. Archdall Reid, for instance, or Professor Karl Pearson? Or, if they approve of "natural selection" by and against consumption, why not introduce plague, and evolve a

race immune against that also? These are the evident ways in which this monstrous creed may be smashed by the *reductio ad absurdum*.

The case of protection against disease is particularly interesting. Given, for instance, such a disease as small-pox, how should we cope with it? An argument might be that we want a strong race, and therefore should allow small-pox to kill off the weaklings, instead of adopting artificial means in order to keep them alive. Thus Darwin himself wrote, forty years ago, that "there is reason to believe that vaccination has preserved thousands, who from a weak constitution would formerly have succumbed to small-pox. Thus the weak members of civilised societies propagate their kind." No modern student of disease could write such a sentence, for the simple reason that we cannot describe susceptibility to small-pox as weakness, any more than we can describe the state of being vaccinated as strength. Susceptibility to or immunity against such a disease is a specific thing; thus vaccination will protect, will make one "strong," against small-pox, but leave one "weak" against so trifling a malady as chicken-pox. To protect a community against small-pox by vaccination, or to abolish tuberculosis, or to extirpate the mosquito of malaria, or the plague rat, is not to allow the weak to propagate their kind; it is simply to protect the weak and the strong from dangers which may affect all.

The Repudiation by Darwin of Contentions Since Advanced in His Name

But let us not suppose that Darwin argued from the foregoing, or from any other cases, that we must allow what is misnamed natural selection to destroy the weak and the kind and the tender among mankind, through the agency of the strong and hard and brutal. On the contrary, he specially repudiated, as if in anticipation, the very doctrine which is now being preached in his name. In the fifth chapter of the "Ascent of Man" he used the following words, now highly in need of quotation: "The aid which we feel impelled to give to the helpless is mainly an incidental result of the instinct of sympathy, which was originally acquired as part of the social instincts, but subsequently rendered . . . more tender and more widely diffused. Nor could we check our sympathy, even at the urging of hard reason, without deterioration in the noblest part of our nature. The surgeon may harden himself whilst performing an operation, for he knows that he is acting for the good of his patient; but if we were intentionally to neglect the weak and helpless, it could only be for a contingent benefit, with an overwhelming present evil. We must therefore bear the undoubtedly bad effects of the weak surviving and propagating their kind."

This last clause does not follow, as we shall see when we come to study the principles of negative eugenics, but meanwhile we note Darwin's unequivocal and emphatic condemnation, as involving "overwhelming present evil," of the truly abominable policy which is now being urged in his name by many exploiters of eugenics in the interests of class ascendency—Eugenists is not a name which the introducer of the word, at any rate, will apply to them.

The Darwinian Assumption of Similarity in the Units Selected to Live

The fact is that not only does Darwin repudiate their teaching, but it is indeed none other than a mad and bad revival of the teaching of the lunatic Nietzsche, which should be nothing but a byword and a reproach in our century. Urged in the name of divine eugenics, for which its founder claimed a place as a factor in religion, this is indeed the abomination of desolation, standing in the holy place.

We pass now to some distinct and most weighty arguments why Darwinism cannot be regarded as a guide and a criterion in eugenics. The individual is the unit in natural selection, as conceived by Darwin. Therefore each individual is weighed on its own merits, as a complete organism, which must stand upon its own legs or not at all. And as the same tests for survival will be applied to all, and as the same characteristics will therefore have survival-value in all, the individuals chosen by natural selection will all tend to be similar and essentially independent.

Variety and Difference in the Units of Society Essential to Civilisation

But what is the structure of human society? It consists of various units, who are evidently unlike in tastes, faculties, and abilities of every kind. This unlikeness is not a misfortune, but a necessity of the social organisation. In the individual body the unity and life of the whole are achieved by the unlikeness of the parts. No one would try to improve the human body by substituting extra nerve-cells for all the kidney-cells or bone-cells, on the ground that nerve-cells were of higher type. We see at once that a condition of

the existence of the body is that it shall have various parts, some higher, some humbler. The case is the same with the "social organism," as Herbert Spencer taught us to call it. The variety and difference between its units are essential if they are to be built up into a high form of civilisation. This is what the economists call "the division of labour," and it requires great natural variety of endowment, as in the case of liver-cells and nerve-cells, if it is to be most effectively carried out.

Hence Mr. Benjamin Kidd, many years ago, showed that natural selection is necessarily and rightly superseded in human society, just because society is a society, and not an aggregate of independent, competing individuals. We can imagine the consequences if, say, the human body were to be subjected to a struggle for existence among its various types of cells. The cells of the brain would instantly succumb to and be digested by the cells of the stomach, the leucocytes would dissolve both, and there would be an end. If society is really an organism, necessarily composed of unlike units, the same truth must hold.

The Argument for Diversity as Stated by Professor Bateson

Here is the very notable paragraph, from the lecture above referred to, in which Professor Bateson has lately expressed this one, among the many conclusive arguments against natural selection, as a eugenic principle: "I lay stress on this aspect of the social problems [the unlikeness of men], because I have seen several times of late the claim put forward that the teaching of biological science sanctions a system of freest competition for the means of subsistence between individuals, under which the fittest will survive and the less fit tend to extinction. That may conceivably be a true inference applicable to forms which, like thrushes, lead independent lives; but so soon as social organisation begins, the competition is between societies and not between individuals. Just as the body needs its humbler organs, so a community needs its lower grades; and just as the body decays if even the humblest organs starve, so it is necessary for society adequately to ensure the maintenance of all its constituent members so long as they are contributing to its support. The simple hydroids, such as Tubularia, live alone, and no doubt compete freely against each other; but hydroids which remain united as compound forms have to let the food circulate among those degraded components which never even develop mouths, and all their lives function as tentacles. A body all muscle would be as helpless as a nation of Sandows; nor would a nation of Newtons live much longer than a brain removed from the skull. . . . Society would do well to restrain competition between its parts so far as to ensure proper food and leisure for the lower grades of producers. How that restraint is to be effected is a question for the practical economist. Some such measures of restraint we have already enacted—on the whole with good results. . . . For if society is in reality an organism, society must apply restraints on the undue growth of its parts analogous to that co-ordinating mechanism which controls the growth of organs in the body."

How Natural Selection Applied to Mankind Would Give the Best No Chance

No apology is needed for the length of this quotation, for it constitutes the express repudiation of the application of Darwinism to eugenics, by the foremost living student of heredity, and one who has repeatedly endorsed the principles of, at any rate, negative eugenics. Professor Bateson is here arguing especially for the giving of fair conditions to the workers who constitute for a modern society, under more or less novel forms, the "hewers of wood and drawers of water." But that is by no means all. The argument against the application of natural selection to human society applies with far greater force, in the judgment of the present writer, when we look at the rarest and most valuable types of mankind. We have already argued that, if cell-survival in the human body were thrown open to competition, the nerve-cells would have no chance. Similarly, if natural selection were allowed free play in human society, and all types had to compete for existence, nothing is more certain than that the poets and musicians, and dreamers and idealists, and men of peace and pioneers, those given to books and hating machinery, and many valuable and indispensable types beside, would be immediately exterminated.

The Renunciation of the Natural Selectors by Sir Francis Galton

Sir Francis Galton always protested against the idea that eugenics seeks to breed for any standardised type. In his last paper before the Sociological Society, when he began the modern eugenic campaign, he used the following words: "There are a vast number of conflicting ideals, of alternative characters, of incompatible

civilisations; but all are wanted to give fulness and interest to life. Society would be very dull if every man resembled the highly estimable Marcus Aurelius or Adam Bede. The aim of eugenics is to represent each class or sect by its best specimens; that done, to leave them to work out their common civilisation in their own way. . . . Special aptitudes would be assessed highly by those who possessed them, as the artistic faculties by artists, fearlessness of inquiry and veracity by scientists, religious absorption by mystics, and so on. There would be self-sacrificers, self-tormentors, and other exceptional idealists, but the representatives of these would be better members of a community than the body of their electors."

This quotation from a paper now classical will suffice to show that Sir Francis Galton would have had no sympathy with the reactionary cry in favour of natural selection, which has arisen since his death. Natural selection would not leave much of the mystics and self-sacrificers, for instance. But the argument, as we have already seen, is far stronger than is suggested by the observation that society would be very "dull" if all men were alike.

The Champions of Natural Selection Among Men the Enemies of Society

The real argument is that, dull or otherwise, society could not exist if all men were alike; and that would be the inevitable and necessary consequence of natural selection just in so far as it was effective. In point of fact, society exists because we are variously fitted to bear one another's burdens, each according to our contrasted aptitudes, as in the wonderful society we call the human body. In a word, just as the existence of the individual organism is the negation of natural selection among its units, so is the existence of the social organism; and the champions of natural selection are therefore the enemies of society.

Darwin's famous doctrine of sexual selection has fared very hardly in recent years, and modern ornithologists cannot credit it with, for instance, the production of the plumage and the song of male birds, as its author did. He was, of course, arguing to the lower animals from ourselves, and sexual selection is a very obvious fact among ourselves. If in any human society there is competition for mates among the members of either sex, some will be taken and others left, according to the psychology of the selectors; and if the factors of selection be in any degree inherent or genetic, the quality of the race will be proportionately affected. Here, then, is the subsidiary theory of Darwin's which requires to be most carefully considered by the Eugenist. In justice to that illustrious pioneer, we must further remember that he never preached the all-sufficiency of natural selection as an instrument of organic evolution. He left that to his followers. For himself, he always attributed some influence in racial modification to the conditions of life; so that, while Darwin's followers are Darwinians, Darwin was a Larmarckian. Eugenics also will discover that it cannot ignore the theories of Lamarck, notwithstanding their long period of neglect by biologists until very recent years.

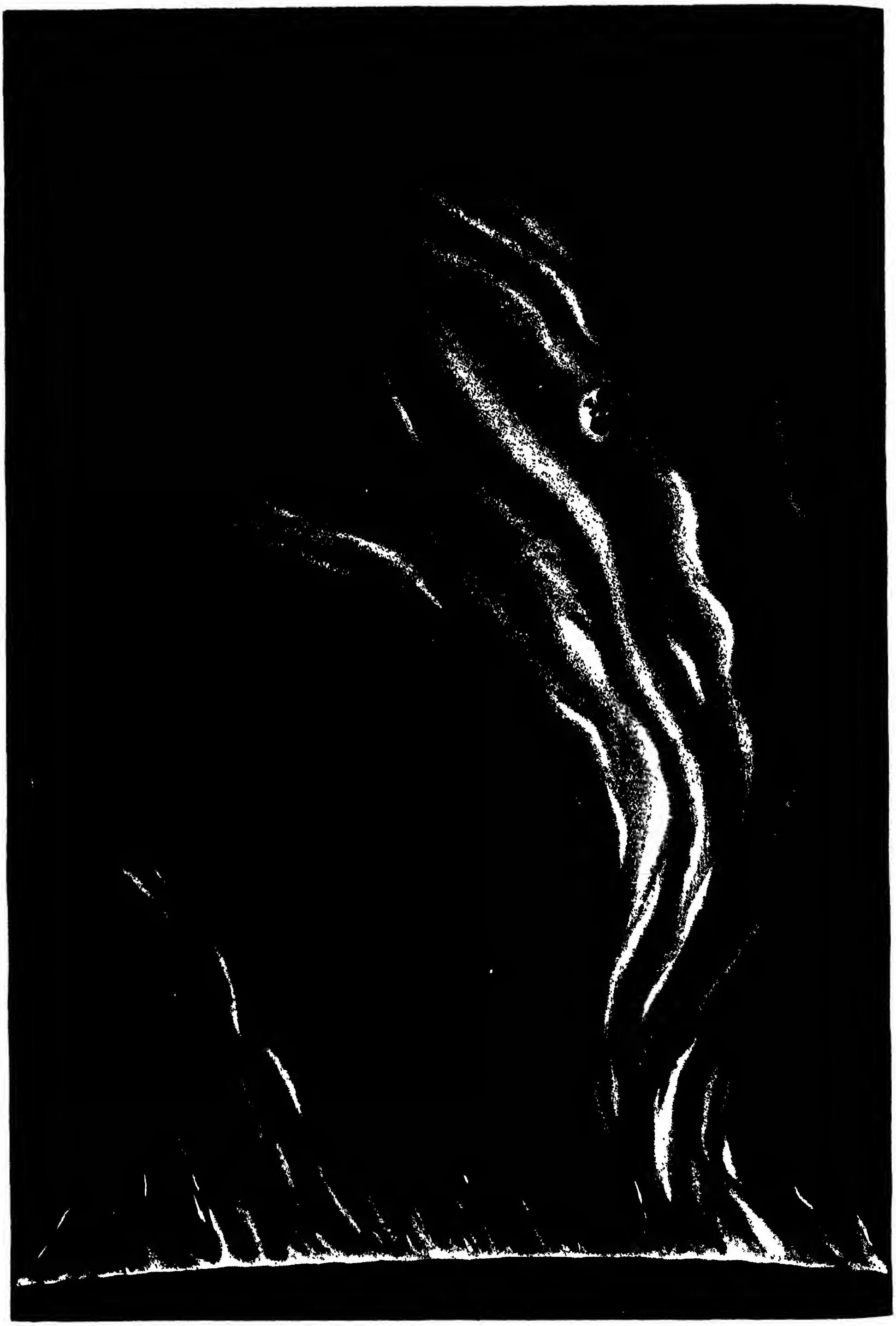
Summary of the Argument Against Basing Eugenics on Darwinism

Such, then, are the relations between Darwinism and eugenics. The initial objection to founding the one upon the other is that the differences which are selected, according to Darwinism, are in the main not transmissible, in the judgment of modern biology; and are therefore useless for the Eugenist. If this argument as to the nutritive character of "fluctuations," and their consequent non-transmission to offspring, however stringently they be selected, is applicable to the lower forms of life, it is supremely applicable to man, whose individuals, above all during youth, are subjected to a far wider range of nutritive or nurtural conditions than are those of any other species. If, therefore, the greater part of what natural selection selects in those species are differences due merely to varying nurture, and are therefore racially inconsequent, much more does the objection apply to man, in whom "fluctuations" due to differences of nurture must be more marked and important still.

The Irony of a Descent to Natural Selection as the Means of Racial Elevation

The other objections, above detailed, depend upon the fact that the whole theory of natural selection, apart from this objection on matters of fact, has been misunderstood by those who, against the authority both of Darwin and Galton, and with Nietzsche as their most responsible champion, preach the descent to natural selection as the sole means of racial elevation. We must therefore turn elsewhere than to Darwinism for our guidance; and it now behoves us to see what sanction and direction we can obtain from genetics before we proceed with the practice of Primary Eugenics.

THE FLAMES THAT RUSH OUT FROM THE SUN



Perhaps the most remarkable phenomena of the sun are the prominences that project in the form of fiery clouds from the chromosphere, which, itself an ocean of fire in ceaseless agitation, completely surrounds the sun. The prominences are of immense extent, often ten times the diameter of the earth, which is represented in this drawing to scale.

OUTER PARTS OF THE SUN

Photographing by the Use of the Spectroscope Things Invisible in the Sun's Blinding Light

THE UNKNOWN ELEMENTS IN THE SUN

We have seen that the great mass of the sun consists of a central core, or nucleus, of gases and metallic vapours. Heated to inconceivably high temperatures, and existing under enormous pressures, these gases are supposed to have a highly viscous consistency, like that of putty, without losing the gaseous condition. We have seen, also, that the same gases, in the atmosphere around the sun's nucleus, become comparatively cooled at the surface as they radiate their heat into space. They are therefore partially condensed into the liquid condition of droplets, and probably, also, into the solid condition of crystals, thus forming the photosphere—a mantle of incandescent clouds floating in an atmosphere of the same gases and vapours, completely enveloping the sun and constituting his visible surface. And we have further seen that this mantle, which plays precisely the same part in producing sunlight as the domestic incandescent mantle plays in producing gaslight, is the seat of those disturbances which are known as faculæ and sunspots.

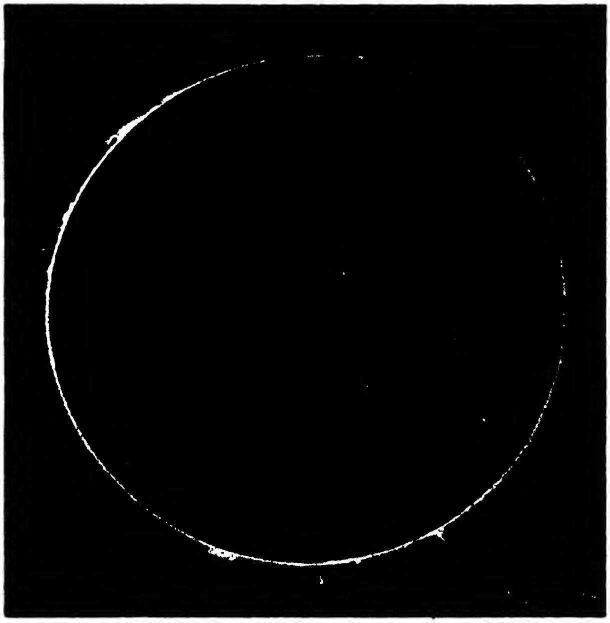
But though we have now considered the interior and the visible surface of the sun, by far the greater part of his bulk or volume remains to be described. The sun extends outward into space far beyond his brilliant photosphere, and we have now to study these outer and invisible parts. Outside the photosphere is the *chromosphere*, and outside the chromosphere is the *corona*—two vast envelopes of extraordinary beauty and interest; but their light, though bright enough in itself, is too feeble to be seen in the presence of the effulgence of the incandescent clouds. The daylight quenches their radiance just as it veils the light of the stars. For this reason all earlier knowledge of the outer sun was gained only during its brief appearances to vision at the times of the sun's eclipse; for when his major light is blotted out by the interposed body of the moon, his minor lights, extending outward round the moon's screen, may be seen for a few fleeting moments. Means have now been discovered for seeing the chromosphere at all times when the sun can be seen, but observations of the corona are still only possible during periods of eclipse.

The whole subject of the eclipses of sun and moon will be considered in some detail in a later chapter. Here we need only remember the fact that the apparent diameters of the sun and moon, as seen from the earth, are almost exactly equal. The actual diameter of the sun is about 400 times that of the moon, but his distance exceeds the distance of the moon in a corresponding degree. In a total eclipse of the sun, owing to this equality of the apparent diameters, the disc of the moon may for a moment cover the sun's disc, cutting off all the light of the photosphere, and so making visible the outer and less-brilliant parts of the sun. In such an eclipse, if the apparent diameters of sun and moon were exactly equal, totality would only last for an instantaneous fraction of time. But the relative distances of the sun and the moon from the earth vary within certain limits, so that the apparent diameter of the moon is sometimes larger than that of the sun, and under those circumstances the total covering of the sun's disc may last several minutes. In that case the sun's edge may first be studied as the forward edge of the moon cuts off the last thin curved line of his disc; and then again, some minutes later, just before the moon's backward edge allows the first thin line of his light to emerge. What, then, will be seen at the edge of the sun?

Let us suppose the sun's disc to be

entirely covered, but just about to emerge from behind the moon. All that we can see at present is the moon, looking like a vast black ball; and streaming outward from behind it is the bright, mysterious glory of the corona. But suddenly, at the edge of the moon where the sun is to reappear, we see a thin curved line round her edge, of a deep, dusky blood-red colour. For a few seconds it glows and widens. Then it is suddenly extinguished, for the edge of the sun's dazzling white disc has emerged, and his accustomed daylight has quenched these lights of his outer parts—the nebulous radiance of the far-flung corona and the blood-red fires which closely envelop his surface.

Or very likely the appearance will be somewhat different. The first sign of the reappearance of the sun may be, not the dusky red curve of his edge, but isolated points and patches of the same colour, emerging from behind the moon like lurid stars, or perhaps suggesting rosy clouds hovering upon the moon's surface. These fiery points and patches, of which there may be one or two or several, grow larger and glow brighter, and are united in the ruddy rim of the sun as it comes into vision; and, together with it, they swiftly disappear before the returning majesty of his light.



THE CHROMOSPHERE AND PROMINENCES
From a photograph by M. H. Deslandres

This ruddy mantle of flame, surrounding the mantle of incandescent clouds, is known as the chromosphere; and those tremendous projections of flame and fiery cloud, which are here and there and now and then thrown up from the chromosphere, and appear behind the edge of the moon preceding the emergence of the sun, are known as the prominences or protuberances.

The chromosphere lies immediately above the photosphere, and is divided from it by a well-defined surface. It is like an ocean of fire, in ceaseless and furious agitation, completely surrounding the sun. Of course, it is not fire in the ordinary sense of the term, for it does not arise from the burning of any gaseous or other materials. But it does consist of flames of incandescent gas, apparently pouring forth at every point of the sun's surface, forming in its lower parts a continuous furnace of great depth, and in its higher parts flaming and spouting upwards in these prodigious prominences. It is now known that the chromosphere is between five and ten thousand miles in depth, and that it consists principally of hydrogen, with which, however, other gases are also present.

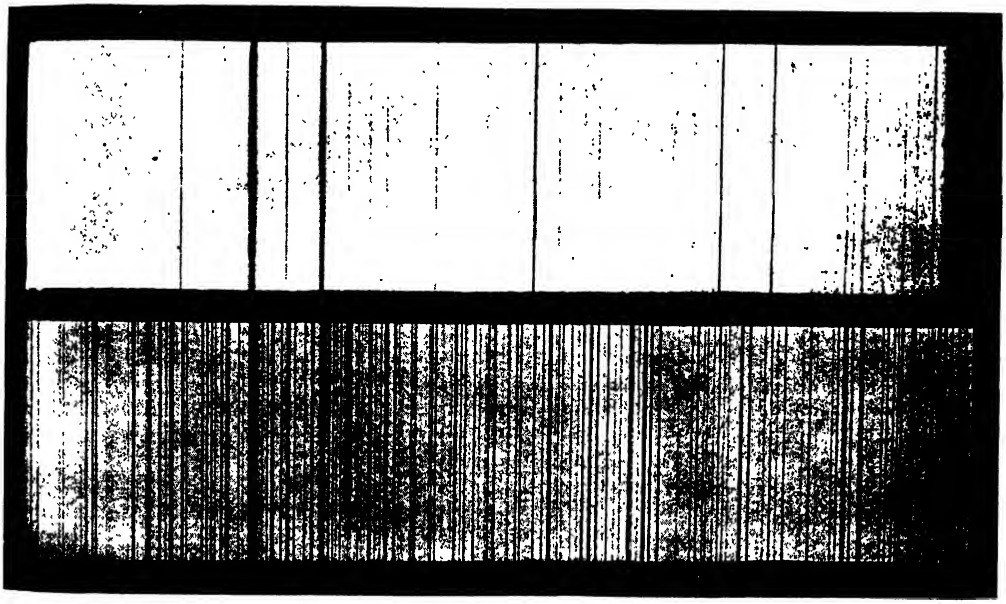
The vision of the chromosphere which is obtained at a total eclipse, though very striking, is of course very rare, and never lasts for more than a few seconds. The present knowledge of its nature would therefore have been quite unattainable if an ingenious discovery had not shown that this ruddy envelope of the sun, and its prominences, may be viewed in broad daylight, and even photographed, by means of the spectroscope. As the resources of that instrument have been developed, it has been induced to reveal the chromosphere and prominences in three very remarkable ways.

During an eclipse which traversed the Indian peninsula in 1868, several astronomers made a spectroscopic examination of the prominences, and found that these towering flames threw a bright-line spectrum, thus proving that they consisted of incandescent gases. At the same time it was shown that hydrogen was the predominant element in them. But one of the astronomers at work, named Janssen, made a far more important discovery. He realised that the spectrum of the

chromosphere was so bright that it ought to be visible in ordinary daylight, and, making the experiment next day, succeeded in obtaining the bright lines of the prominences. The report of his discovery reached Europe simultaneously with the announcement of the same discovery by Sir Norman Lockyer, who had solved the problem independently.

In order to see the comparatively faint light of the prominences in the full glare of sunlight, both of these astronomers had devised the same ingenious method. As we saw in the preceding chapter, an incandescent solid or liquid throws a continuous spectrum, but an incandescent gas throws a discontinuous spectrum of bright lines. The light of the photosphere, or ordinary sunlight, is of the former kind, but the light of the chromosphere and prominences is of the latter kind. When, therefore, an image of the sun is formed by a telescope, and the slit of the spectroscope is directed to the edge of the sun's disc in the image, the spectroscope receives at the same time the light of the photosphere and the light of the chromosphere and prominences. That is to say, a continuous spectrum is superimposed upon a spectrum of bright lines. But the bright lines are very faint and the continuous spectrum of sunlight is very strong, so that the former are masked by the latter. For example a faint red line from the chromosphere, falling as it does upon exactly the same shade of red in the strong continuous spectrum of ordinary sunlight, must evidently be quite indistinguishable. Yet the observer of the chromosphere wants to see the line spectrum. He has no use for the continuous spectrum; it only serves to obliterate the bright-line spectrum; and yet he cannot shut it out. How is he to deal with it, so as to let the bright lines shine out clearly?

The method which Janssen and Lockyer separately devised consists in spreading out the continuous spectrum, and with it, of course, the bright-line spectrum also, until they are both very wide; that is to say, until the red end of the spectrum is very far removed from the violet end. By this process of spreading out, the continuous spectrum becomes fainter and fainter, as the light received through the slit of the spectroscope is distributed over a larger area. But through all the spreading out, the bright-line spectrum remains of the same intensity as it was at first, the only difference being that its lines are removed further and further from one another. It is obvious that if the spreading out of the spectrum is carried on far enough, the continuous spectrum of ordinary sunlight will become so faint as to be negligible, and



COMPARATIVE SPECTRA OF THE SUN WHEN IT IS HIGH AND LOW IN THE HEAVENS

These two photographs of a part of the spectrum of the sun bring out graphically the meaning of the dark lines. The lines are more numerous in the lower band, owing to the fact that the rays pass through a greater amount of the atmosphere of the earth when the sun is low on the horizon. These photographs are by Mr. George Higgs.

the bright-line spectrum of the chromosphere and prominences will stand out clearly.

How is the spreading out of the spectrum effected? Very simply. By passing the light through a sufficient number of prisms, each of which separates the variously coloured elements of the spectrum to a greater degree than before. In a form of spectroscope often used for this purpose the light is dispersed twelve times, by passing through as many prisms. It may also be asked why, with this repeated dispersion, each individual line of the bright-line spectrum from the chromosphere does not itself become widened out so as to cover a larger area and consequently become fainter. Why should the continued spreading out of the spectrum merely have the effect of separating the lines further from one another, leaving them individually as narrow and therefore as bright as at first? The reason is that each of these lines is spectroscopically of one kind of light only; all the light which it contains is absolutely of the same wave-length. The effect of each prism on any such ray of homogeneous light is to bend it as a whole, but obviously cannot be to bend some of its parts more than others, so as to widen it.

The spectrum of the chromosphere has received much study. Certain lines, which may be regarded as really characteristic of it, are always present, and indicate hydrogen, helium, calcium, and one or two unknown elements. The corona line, so called because it is given by the light of the corona, is found also in the light of the chromosphere. But this vast envelope of incandescent hydrogen and other gases is subject to great disturbances, especially in the vicinity of sunspots; and on these occasions there are probably intrusions into the chromosphere of metallic vapours from the photosphere below. This may explain the frequent appearance, in the chromosphere spectrum, of a great number of lines characteristic of iron, sodium, magnesium, manganese, and other metals. But these intruding elements quickly disappear again, leaving only the spectrum proper to the chromosphere.

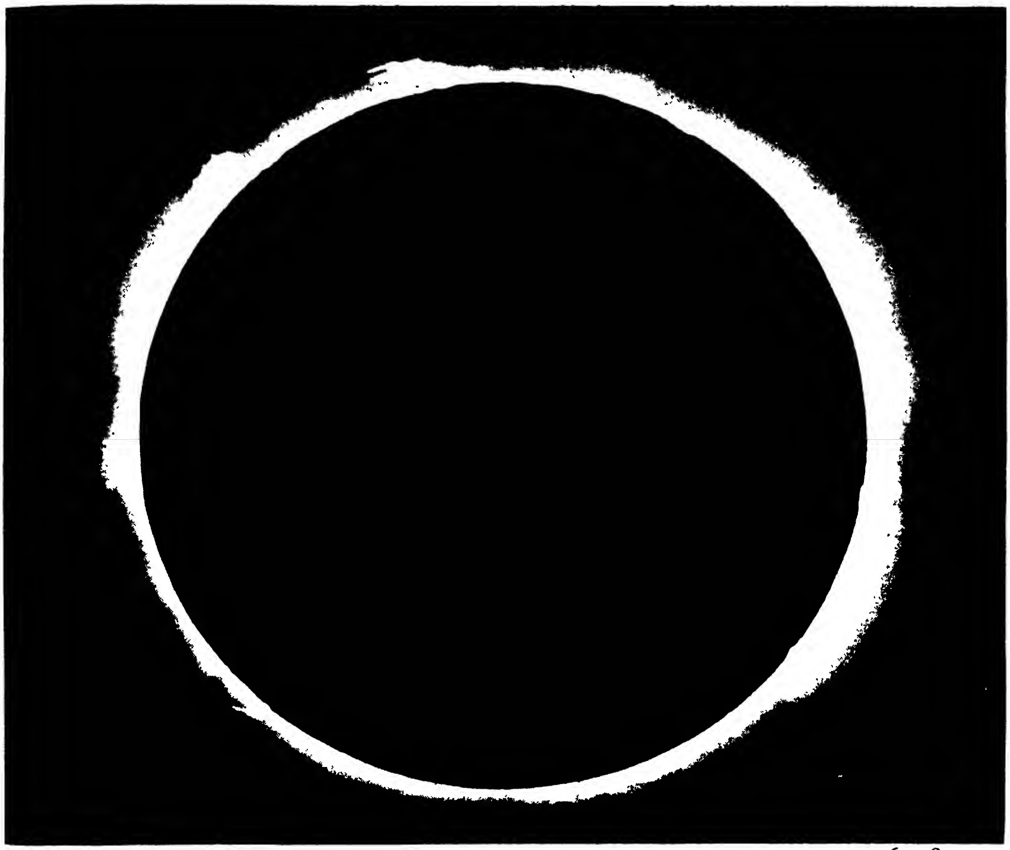
It was said above that there are three remarkable ways in which the spectroscope is used to reveal the chromosphere and its prominences. With the first of these, the spreading out of the spectrum so as to make it possible to examine the bright lines of the chromosphere in full sunlight, we have already dealt. The second method, which is a development from the first, was devised by Sir William Huggins. It enables the observer to get a telescopic view, in broad daylight, of the chromosphere and the prominences, so that he can study their form and their changes. He sees through the spectroscope, not their spectrum, but the objects themselves; and is even able to photograph them, thus securing some of their features which the eye cannot perceive.

An image of the sun, as before described, having been formed by a telescope, the slit of a spectroscope of several prisms is directed so as to lie along the edge of the image. As before, ordinary sunlight will be received along with the far fainter light of the chromospheric flames. As before, the spectrum of the sunlight will be spread out until it is too faint to give any trouble, and the bright lines of the chromosphere will be widely separated from one another. Each of these bright lines is, of course, an

A LARGE SOLAR PROMINENCE SEEN DURING THE ECLIPSE OF AUGUST 30, 1905

From a photograph by Cte. De la Baume Pluvinel

image of the slit, in light of some one definite wave-length and therefore of one pure shade of colour. If the observer now concentrates his attention on one of these bright lines, he is actually looking at the chromosphere and prominences at one definite place on the edge of the sun's disc, through an exceedingly narrow slit. He cannot see anything of their form or structure, but this is only because the slit is so very narrow. But if he widens the slit by means of the screw which regulates its aperture, the



THE PROMINENCES ON THE SUN SEEN DURING THE TOTAL ECLIPSE OF APRIL 16, 1893

From a photograph by Prof. J. M. Schaeberle; the photographs on page 2105 are by Dr. A. Schuster, Sir Norman Lockyer, Mr. S. Kostinsky, and Sir W. H. M. Christie

details of the chromosphere and prominences at that particular portion of the sun's disc begin to appear; and when the slit is open enough, there is a minute picture, all in one colour, in the widened bright line of the spectrum. It was thus that Sir William Huggins discovered the possibility of seeing the shape and the changes of the chromosphere and its prominences, in full daylight.

The chromosphere has several bright lines in its spectrum, and any one of these may be opened out in this way, so as to form an image of its shape and of its prominences and their movements. Thus, a picture may be obtained in a blue line of the spectrum, in a yellow line, and in a violet line. But as might be expected from the ruddy colour which the chromosphere presents at times of eclipse, the predominant element in its light is red; and it is therefore through a widened red line that this part of the sun is chiefly studied. Red light, however, is useless for photography. When the camera is put in train with the telescope and spectroscope so as to obtain photographic records of the chromosphere and the prominences, a bright line at the extreme violet end of the spectrum is used. This light, though almost invisible to the eye, has great photographic activity. By its means the American astronomer Professor Hale has produced a wonderful series of photographs of the entire chromosphere with all the prominences which at the time it may happen to show. These photographs, which appear like a fine circle of irregular light on a black

background, are of special value in the study of the rapid changes in the prominences.

These prominences, like the flames of some gigantic conflagration, often move with prodigious celerity, rising and falling, and sweeping in terrific blasts now this way and now that way. Any means by which the velocity of their movements can be estimated is welcome to the astronomer.

How the Spectroscope is Used to Measure the Speed of Flashing Luminous Gases

Here again, for the third time, the spectroscope shows the astonishing diversity of its powers. We have seen how an image of a portion of the chromosphere, and of the prominences upon it, is viewed through a widened bright line of the spectrum. Obviously, the movements which any prominence makes in the plane of that picture can be estimated easily enough. But how is it possible to estimate those movements which it makes towards or away from the observer? How can the speed of its motion in the line of sight be measured? When we watch the movements of any distant terrestrial object, it is easy enough to see how fast it is moving to right or left, or upward or downward, but it is often difficult to tell whether it is moving in the line of sight at all, and, if so, whether it is approaching or receding.

But in the case of a luminous body of gas moving at high speed, such as one of these prominences, the spectroscope can be made to give exactly that information. It can show whether this body is approaching or receding from the observer, and can even indicate approximately its speed along the line of sight. If, for instance, the flame is approaching, the lines of its spectrum, instead of falling on their accustomed places in the scale of the spectrum, are displaced somewhat toward the violet end of the scale. On the other hand, if it is receding, the lines which characterise it are displaced towards the red end of the spectrum; and the degree of this displacement is the measure of the flame's velocity along the line of sight.

The Effects of Approaching or Receding Light Comparable with Approaching or Receding Sound

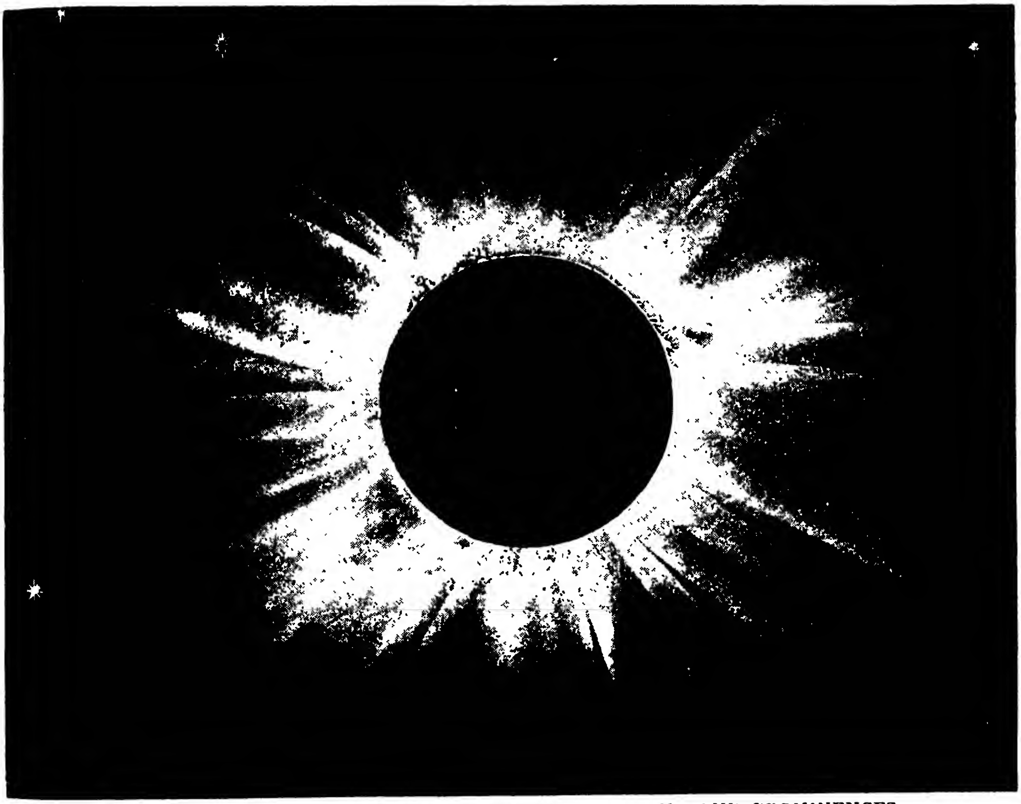
The explanation of this method of ascertaining the speed of the movement towards or away from the observer is simple enough If the luminous gas be stationary, it sends light of certain definite wave-lengths, showing themselves in certain definite bright lines of the spectrum. Let us consider one of those bright lines alone, neglecting the others. It stands in that definite place on the scale of the spectrum, because its waves succeed one another at a definite speed. If the speed with which its waves succeed one another be increased, it must move a little away from the red end, characterised by the slowest vibrations, and a little towards the violet end, characterised by the quickest vibrations. If, on the contrary, the speed with which its waves succeed one another be diminished, it must move a little away from the violet and towards the red. But obviously, if the luminous gas which is the source of these vibrations should begin to rush away from the observer, its light-waves on reaching the observer, will follow one another less rapidly than before, and the bright line they make in the spectrum will consequently shift towards the red. Similarly, if the flame begin to rush towards the observer, its light-waves will follow one another more rapidly than if it were stationary, and its bright line will therefore be shifted towards the violet end of the spectrum. The effect has been well compared to the change in pitch of a locomotive's whistle as it rushes past the listener on a station platform. The engine is making the same sound all the time, but the sound is heightened by its swift approach, and is lowered as it rapidly recedes. So, just as it passes the listener, the sound falls through a considerable interval.

The Prominences of the Chromosphere, Seen Momentarily in Eclipse, Made Steadily Apparent

The prominences or protuberances of the chromosphere were first noticed as brilliant red, starry points of light on the edge of the moon, during total eclipse of the sun, but owing to the spectroscopic methods we have already described their principal features have now been thoroughly ascertained. They are closely associated with those activities or disturbances of the sun which result in the production of sunspots and faculæ. They are numerous in those years when sunspots are at their maximum, and are few in number at the periods of minimum sunspots. Moreover, both sunspots and faculæ, but especially the latter, when seen at the edge of the sun's disc, are found to be closely accompanied by prominences. The number of large prominences visible at one time round the edge of the sun varies from zero to twenty or thirty; but it must be remembered that those seen in profile at the circumference of the disc only form a very small proportion of those which must be simultaneously present over the whole surface of the sun. Although prominences occur in every region of the sun, from the

equator to the Poles, they are most numerous in the latitudes chiefly frequented by sunspots.

The prominences vary much in height, and sometimes reach prodigious elevations. A large proportion of them attain a height of from 20,000 to 30,000 miles, not many exceed 100,000 miles, but isolated examples have been recorded as attaining elevations of 200,000 miles, 300,000 miles, and even more. Professor Young observed one in 1888 that reached a height of 350,000 miles. His account of it is interesting, as showing the enormous rapidity with which these columns of flame are often formed. "When first seen," he says, "on the south-east limb of the sun, about 10.30 a.m., it was a 'horn,' of ordinary appearance, some 40,000 miles in elevation, and attracted no special attention. When next seen, half an hour later, it had become very brilliant, and had doubled its height; during the next hour it stretched upwards until it reached the enormous altitude mentioned, breaking up into filaments that gradually faded away, until, by 12.30 p.m., there was nothing left. A telescopic examination of the sun's disc showed nothing to account for such an extraordinary outburst, except some small and not very brilliant faculæ. While it was extending upward most rapidly, a violent cyclonic motion was shown in the lower part by the displacement of the spectrum lines." The last remark refers to the movements of the incandescent gases along the line of sight, towards and away from the observer. The motion of prominences and of their parts often attains amazing velocity, a speed of 200 miles a second having been ascertained in certain cases.



A DRAWING OF AN ECLIPSE, SHOWING THE CORONA AND PROMINENCES

This drawing represents an eclipse when sunspots are at their maxima, and the prominences are consequently numerous. The spots of bright light at the lower left hand of the disc peeping through the valleys between lunar mountains are known as "Bailey's Beads."

Two principal kinds of prominences are clearly distinguished from one another, and are known respectively as the quiescent and the eruptive. The quiescent kind are clouds of incandescent hydrogen, and have sometimes been seen to form spontaneously in the atmosphere in which they float, without having any contact with the chromosphere below. More often they are at the summit of one or more thin, irregular

columns that expand as they rise from the chromosphere to form the widely floating clouds. The several kinds of clouds with which we are familiar in our earthly atmosphere are closely reproduced in the forms of these quiescent prominences. Their changes are slow, so that the same cloud may retain its form for several days. Their spectrum, showing principally hydrogen, though often mixed with magnesium and sodium, marks them as having a different origin from the other kind of prominences caused by violent eruptions and showing a spectrum bright with the lines of many metals.

The Extraordinary Variety of Changing Forms in the Eruptive Prominences

These eruptive or metallic prominences, usually closely connected with sunspots, assume an extraordinary variety of forms. Unlike the quiescent prominences, they rise, and change, and disappear with amazing speed. Professor Young describes some of their appearances in graphic words: "Sometimes they consist of pointed rays, diverging in all directions, like hedgehog spines; sometimes they look like flames; sometimes like sheaves of grain; sometimes like whirling waterspouts, capped with a great cloud; occasionally they present most exactly the appearance of jets of liquid fire, rising and falling in graceful parabolas; frequently they carry on their edges spirals like the volutes of an Ionic column; and continually they detach filaments which rise to a great elevation, gradually expanding and growing fainter as they ascend, until the eye loses them." They consist essentially of eruptions of vast masses of gas, driven off from the sun with enormous speed. The eruptive prominences are in general not so high as the quiescent kind, but, on the other hand, prominences of exceptional height are always of the eruptive kind.

Leaving the chromosphere and its prominences, let us turn now to the outermost of the sun's features.

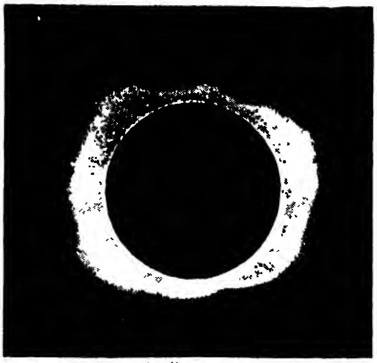
The Great Difficulty of Observing the Sun's Elusive Corona

The corona, or "crown," was well known to the ancients, yet its nature is little understood even now. There are several reasons for this. In the first place, it is visible only at times of total eclipse, so that opportunities for its study are rare and very brief. If an astronomer were to make the examination of the corona the first aim of his life, and were to voyage over the world to see every total eclipse, and were fortunate enough to have clear skies for every one of his observations, after forty years of work he would have seen the corona for about an hour. Again, not many years have passed since the corona was proved beyond question to be part of the sun; it was formerly thought by many to be some transparent feature of the moon, illumined by the hidden sun. But perhaps the chief difficulty lies in the strangely elusive character of the corona itself. Two or more people with equally keen vision, equally well trained, and observing it from the same place, will see the corona quite differently and make quite different drawings of it. This difficulty is not overcome even by photography, not only because photographs often omit features of the corona which were very striking to the eye, but also because the picture obtained varies in an extraordinary degree according to the length of the exposure and the development of the plate. Some impression of the various appearances of the corona may be gained better from the illustrations on these pages than from any description.

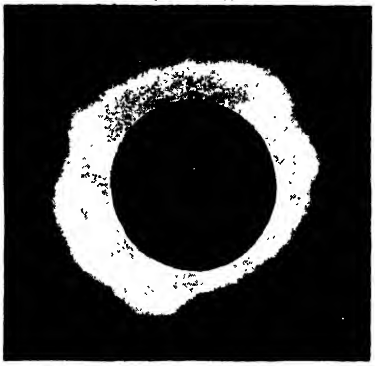
The Various Forms Assumed by the Mysterious Splendour of the Corona

The forms this mysterious splendour assumes seem to be infinitely various. From round a coal-black moon, which at the moment of total eclipse shows visibly its spherical form, there extend outward in every direction threads and films, streamers and banners of light, brighter and more definite at their origin and becoming more faint and nebulous toward their outer extremities. Their direction is mainly but not exclusively radial, for brilliant shafts shoot off at a tangent to the sun, and some are curved like scimitars or even hooks or loops, and others are shaped like leaves. Black rifts of darkness which may also be curved, often cut the halo from centre to periphery. The corona's beams extend outward to vast distances, sometimes attaining a length of many times the diameter of the sun's disc.

The light of the corona is generally described as pearly in colour and appearance. The most various estimates have been formed of its illuminating power. Indeed its extent, and therefore probably its radiance also, are much greater at some times than at others, depending upon the activity of the sun as shown in the sunspots and prominences. Its inner parts are too bright for the eye, if viewed with a telescope without the interposition of a tinted glass, and the evidence seems to show, on the whole, that the entire corona gives more light than the full moon. It reveals the



April 6, 1875



August 29, 1886

August 9, 1896

January 22, 1898

THE CHANGING CORONA OF THE SUN AS SEEN AT VARIOUS DATES

landscape very clearly, though without colour; objects whether near or far are seen distinctly, but somewhat as they are seen in sunlight through dark tinted glasses.

The spectrum of the corona is particularly characterised by a bright green line, that has not been obtained otherwise than from the corona. No terrestial element has been found to give it. It is therefore set down to the existence of an unknown element, to which the name *coronium* has been given. This bright coronal line is found in the solar spectrum as a fine dark line. Besides certain doubtful bright lines, the coronal spectrum contains also the bright lines of hydrogen. It is certain that the corona consists partially of hydrogen and to a much greater extent of coronium, which is far less dense than hydrogen.

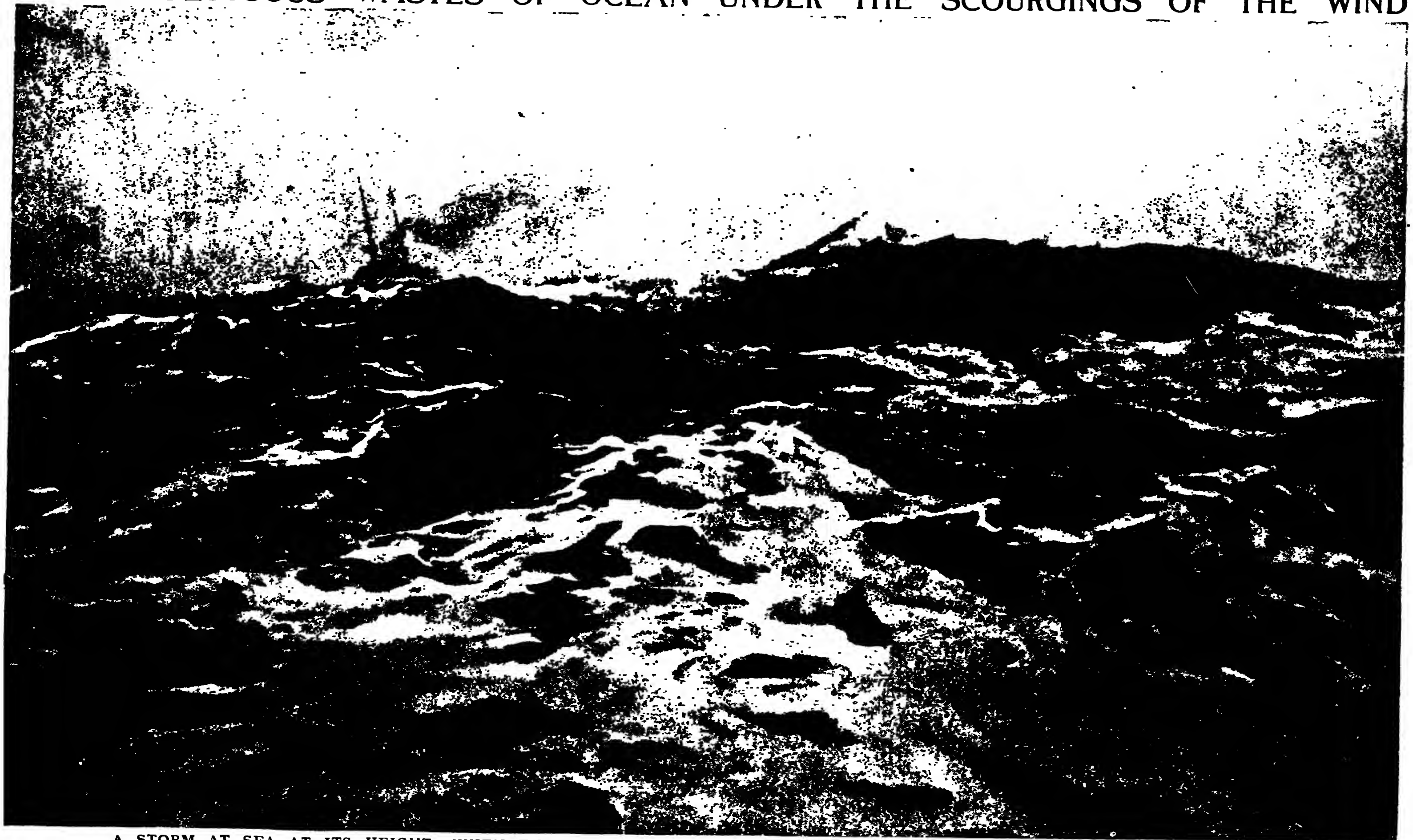
But it consists also, in part, of other elements which are not gaseous at all. There are three main evidences of this fact. In the first place, the bright lines of the coronal spectrum are given just as clearly by those rifts of darkness, which were described above as existing in the corona, as they are given by the brilliant parts of the aureole. This shows that the brightness of the corona cannot depend upon the light which yields its characteristic bright-line spectrum. In the second place, in addition to that bright-line spectrum which is due to its gases, the corona throws also a faint continuous spectrum, which means that some of the light comes from solid or liquid particles. And in the third place, the light from the corona is found to have been partially polarised in such a way as proves that it consists partially of reflected light.

The corona consists therefore partly of an incandescent gaseous atmosphere, extending for a vast distance outward from the sun's surface, and partly of dust or fog or swarms of meteors. But there are almost certainly other factors also.

The wonderfully various arrangement of the shafts of light remains a mystery. The streamers are in general most strongly developed radially from those zones of the sun where sunspots are most frequent; there are often far-reaching equatorial sheets of light, or sheets extending north and south from the Poles. On the whole, the corona, though varying greatly in form, is in each case symmetrical about the sun's axis. There is reason to believe that the far-flung streamers and rays and sheets of light are not due to the gaseous atmosphere of the corona, but consist of light reflected from meteoric particles and dust; and probably the courses which are followed by these beams of light are determined by magnetic influences.

In a word, the nature of the corona is an unsolved problem. "It seems likely," says Professor Young, "that the phenomena of comets' tails and the streamers of the aurora are phenomena of the same order; and though as yet the establishment of this relation would not amount to anything like an explanation of the corona, it would be a step toward it."

THE TEMPESTUOUS WASTES OF OCEAN UNDER THE SCOURGINGS OF THE WIND



A STORM AT SEA AT ITS HEIGHT, WHEN THE GREATEST SHIPS ARE OBSCURED BY THE RISE AND FALL OF THE WAVES

A STUDY OF SEA-WAVES

Their Formation, Height, Depth, Force, Destructive Power, and the Problem of Coast Defence

RAIN STRONGER THAN THE MIGHTY SEAS

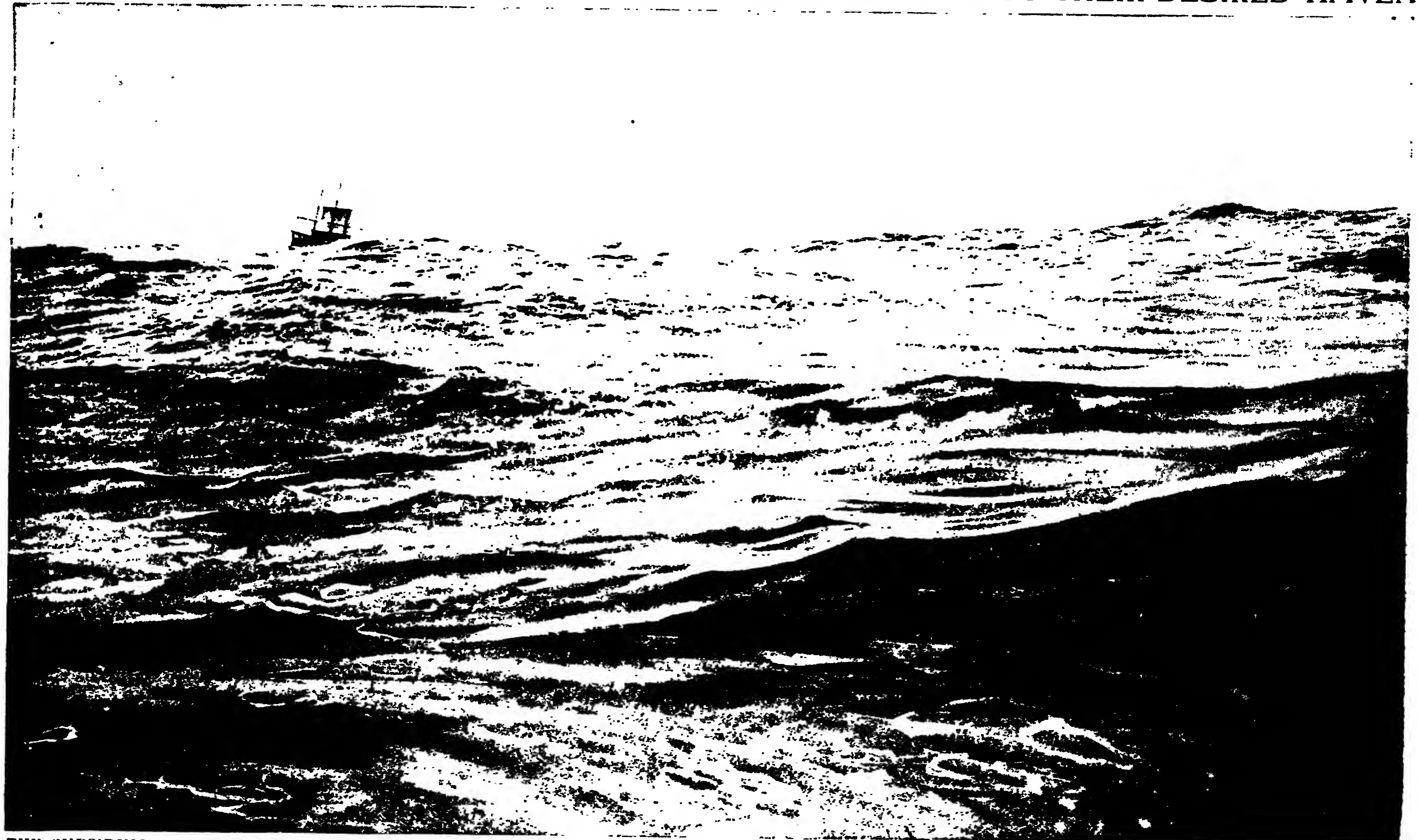
THE moon and the winds allow the sea little rest; they pull and push its waters up and down, here and there. Sometimes there is merely a heaving sway, sometimes just a ripple, sometimes the long billows come like the ranks of an unconquerable army, sometimes there is surge and foam, but always on a sea of any size there is wave-movement. Waves, as commonly understood, are disturbances of the surface of the sea due mainly to the wind, but, of course, the lunar tides always play their part in the resultant motion. The disturbance consists essentially not of a forward stream, but of a progressive up and down motion of the water. Each part of the water traversed by the wave rises upward beyond mean level, and then sinks down beneath mean level, but no individual wave travels forward as it appears to do; and if a cork be floated on the water it will be seen to rise and fall, and not to travel forward unless carried forward by a forward movement of the water, apart from and independent of the up and down wave motion. Sea-birds floating on the water also illustrate this up and down motion, The waves, in fact, no more travel along than do the waves of a field of waving corn; in both cases the forward movement is an optical delusion, though in the case of the sea, as we have previously mentioned, the upper layers of water are sometimes swept off the surface by the wind, as a squeegee sweeps the mud off the streets.

The height of a wave depends on the force that produces it, and on the length of time the force is in action. Thus, when a gale blows for several days the waves become bigger and bigger. Thus, also, when a wave blows off the land the waves increase in magnitude with increasing distance from the shore. Further, waves are higher the deeper the water in proportion to its area, and waves in salt water are higher than waves in fresh water. Lake Superior, for instance, would be whipped by a wind into higher waves if its water were salt, or if it were larger in area, or of greater depth. In the shallow British seas the waves are never more than 15 or 20 feet high, and in the German Ocean and Mediterranean 13 feet is about the maximum, whereas in the deeper and larger Atlantic they often far exceed that height. Scoresby, voyaging from Liverpool to Boston in 1847, measured waves from 26 to 29½ feet in height, and found that the average height was about 19 feet. On a more stormy return voyage, in the subsequent year, he found that the average wave measured 30 feet, and one wave he measured reached 43 feet. A wave of 33 feet has been measured in the Pacific; and off the Cape of Good Hope Sir James Ross noted a wave of 39 feet. In the Bay of Biscay, proverbial for its storms, no higher wave than 36 feet has been measured. Some observers have asserted that they have seen waves over 100 feet high, but it is certain that no wind-raised wave ever reached that height, and it is probable that 50 or 60 feet is the maximum height of waves raised by wind in the open sea. The highest waves, it may be noted, occur not during the fiercest storms but are the cumulative result of gales blowing persistently in the same direction.

Often waves spread out far beyond the actual centre of a storm in the form of a long, heaving undulation known as a ground swell, which is most marked where the water becomes shallower, and which eventually terminates in a series of *rollers*, or *breakers*, as the friction of the bottom impedes the progress of the deeper part of the swell.

We have said that waves in open sea do

HE MAKETH HIS STORM A CALM, AND SO HE BRINGETH THEM TO THEIR DESIRED HAVEN



THE SUBSIDING OF THE STORM AS THE SPENT WAVES OF MID-OCEAN SINK GRADUALLY TOWARDS REST A PHOTOGRAPHIC STUDY BY MR. F. J. MORTIMER

not exceed the height of 50 or 60 feet, but the breakers of breaking waves may burst in surf and spray to much greater heights. At Nosshead lighthouse, in Caithness, large volumes of water are thrown up as high as the lantern—that is to say, 175 feet above sea level. The Bell Rock lighthouse, 112 feet high, is often enveloped in spray and foam. The windows of Dunnet Head lighthouse, at a height of upwards of 300 feet above sea level, are sometimes broken by stones carried up by the sheets of sea water that break over the building.

So much for the height of waves. Next, we must consider how deep the disturbance goes. Theoretically, it is probable that a wave is propagated downwards for a distance 350 times its height. Thus a wave 33 feet in height would reach to a depth of about 1¾ miles. This may be true theoretically, but the force of the waves diminishes in geometrical proportion with the depth, and, so, soon ceases to be appreciable. In some cases the waves are certainly effective to a depth of 600 feet, for ground-swell is known to break in hundred-fathom waters. "The Atlantic surge on approaching the West Coast of Ireland displayed itself in a line of waves on the edge of the hundred-fathom soundings," and the sand on the sea bottom at such depths sometimes bears ripple marks. But, as a rule, waves do not cause much disturbance at a greater depth than 300 feet, and below 600 feet there is calm during the wildest storm. In view of the fact that there is calm below a certain depth, it has several times been proposed to build submarine vessels in order to avoid stormy seas.

How wide are waves? What do they measure from base to base? On the average a wave is fifteen times as long as it is high. Thus a wave 5 feet high measures on the average 75 feet from trough to trough; and a wave 50 feet high 750 feet from trough to trough. Since some of the huge Atlantic liners are over 900 feet long, it is evident that they can never sink into the trough of the sea.

WAVES BREAKING ON A RUGGED SHORE

The velocity of the waves depends partly on the length of the wave and partly on the depth of the water. The longer the wave and the deeper the sea, the greater the velocity of the wave. Small waves in shoal water travel as a rule less than twenty miles an hour, whereas storm-waves in deep seas may go at twice that pace. If we know the length and velocity of a wave, we can calculate the depth of its water; and if we know the width of a wave and the depth of the water, we can calculate the velocity of the wave.

The following table, by Airey, shows relative lengths, depths, and velocities:

Depth of the Water in Feet.	Length of the Wave in Feet							
	1	10	100	1,000	10,000	100,000	1,000,000	10,000,00
	Corresponding Velocity of Wave per Second in Feet							
1	2·262	5·320	5·671	5·671	5·671	5·671	5·671	5·671
10	,,	7·145	17·921	17·921	17·933	17·933	17·933	17·93
100	,,	,,	22·264	53·390	56·672	56·710	56·710	56·71
1,000	,,	,,	,,	71·543	168·830	179·210	179·330	179·33
10,000	,,	,,	,,	,,	226·240	533·901	566·720	567·10
100,000	,,	,,	,,	,,	,,	715·430	1688·300	1793·30

Waves caused by earthquakes are very long and very rapid. On December 23, 1854, an earthquake in Japan, at Simoda, started a wave across the Pacific which was recorded in the self-registering tide-gauges of San Francisco and San Diego when it reached the Californian coast. It was calculated from the times of arrival that the earthquake had produced a wave two hundred and ten miles in length, which had travelled at the rate of 6·7 miles per minute. Similarly, two earthquake waves which were produced in Peru on August 13, 1868, and May 9, 1877, were calculated to have travelled to Japan and New Zealand at about the same rate.

The effect of oil in abating waves has been known for ages. The fishermen in the Persian Gulf tow a pricked bladder of oil to assuage the waves when the sea is rough, and similar use of oil is made by the boatmen of Tangier. At Lisbon in rough weather oil is poured on the bar of the Tagus; and Scottish and Norwegian fishermen, when landing through surf, have been wont to squeeze fish-livers to make the oil exude, and then fling the livers ahead of the boat. Whalers in the Southern ocean, too, when the sea is rough, are in the habit of hanging large pieces of blubber on each quarter in order to prevent the water from coming aboard. There is no doubt that oil does abate the waves, but how it acts is not quite certain. Lieutenant Bechler, U.S.N., who has made a special study of the matter, says: "Oil changes the storm-wave into the heavy swell. Its specific gravity causes it to float on the surface; it spreads rapidly and forms a film, like an extremely thin rubber blanket, over the water. Its viscosity and lubricant nature are such that the friction of the wind is insufficient to tear the film and send the individual wavelet to the crest; and while the force of

A SILVER BAND OF SPRAY THROWN UP BY WAVE-FORCE MEETING LAND-FORCE

the wind may increase the speed of the wave in mass, it is as a heavy swell and not in the shape of a storm-wave. The effect is purely a mechanical change in the shape of the wave, and there is no evidence of any chemical action by the oil on the water."

The force of waves is prodigious. Water is a heavy substance, and when flung in large quantities it acts like a colossal battering-ram. The engineer who built the Eddystone lighthouse calculated that during storms it would be exposed to a pressure of 3013 pounds on the square foot, but at Skerryvore lighthouse, on Tiree, more than twice that pressure has been recorded; and at the Bell Rock lighthouse, at the mouth of the Tay, the tremendous pressure of 6720 pounds has been registered. And even greater force than this has been found in some instances. On several occasions the winter breakers in the North Sea and Atlantic have been found to exert a pressure of nearly 7000 pounds per square foot, and at Dunbar a pressure of about 8000 pounds has been noted.

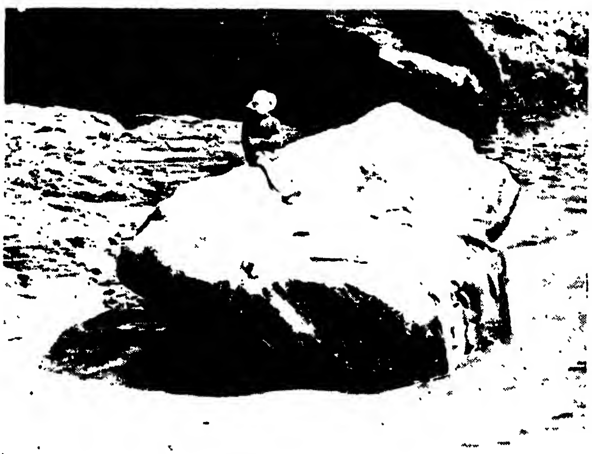
Force of this magnitude can toss boulders like marbles. When the Dhu Heartach lighthouse was being built, a summer gale occurred which carried back into deep water, "like leaves out of a book," fourteen stones each weighing about two tons, even though they had been fixed in their places 37 feet above high-water mark. On any coast, indeed, exposed to heavy seas, blocks of stone or mortar tons in weight may be tossed about. At Barra Head, in the Hebrides, a block of stone weighing forty-three tons was carried nearly two yards by the breakers. During a cyclone in the Azores in 1887, rollers 25 or 30 feet high "came with such force upon the breakwater that vast blocks of stone were tossed about like pebbles, and thick iron stanchions snapped as if they had been bits of stick." The full force of the Atlantic rolling in the Bay of Biscay is sometimes terrific. Blocks of masonry 36 tons in weight have been thrown for 11 or 13 yards; "one block was even raised nearly seven feet, carried over the breakwater, then thrown down, and rolled to a distance during the storm." At St. Jean de Luz it has been necessary to employ masses of stone of not less than 80 or 90 cubic yards.


THE SPOILS OF THE SEA—A SUBMERGED FOREST IN MOUNT'S BAY, CORNWALL

But still more wonderful instances of the power of the waves may be cited. "In the Isle of Réunion there is to be found in the middle of a savannah a massive piece of madreporic stone, which is no less than 510 cubic yards in size. It is a piece that the waves have detached from a reef and driven before them across the land."

At Wick Bay, during a futile attempt to construct a breakwater, a great block of concrete weighing about a thousand tons was laid and securely fastened at the seaward end, but the very first winter storm hurled the ponderous block away, and tossed the smaller pieces like bits of cork. Strong iron bars eight inches by three were broken as easily as Samson snapped the withes. Finally, to close this tale of prodigies, it is recorded that "at Plymouth a vessel weighing 200 tons was thrown, without being broken, to the very top of the dyke, where it remained erect, as on a shelf, beyond the fury of the waves."

Considering, then, the mighty force and patient persistence of waves, it is little wonder that the coasts of the world are being constantly sculptured and changed by the assaults of the sea. And the destructive power of the sea is much increased by the fact that it drives compressed air before it like wedges into any crevices in the surfaces that oppose it. The compressed air, again, suddenly expands when the pressure is reduced, and acts almost like an explosive. Further, the waves bombard the coasts with rocks they have already torn from it, and bruise and abrade the land with showers of stones, pebbles, shells, and sand. All along the coast, *needles*, *stacks*, *skerries*, "*drongs*," *caves*, and *coves* testify to the bombardment of the billows. In many places the sea is rapidly encroaching on the land. In 1862, during a terrible hurricane, the sea eroded away a belt of rock at La Hève more than fifty feet thick, and since the year 1100 this cliff has been eaten away at the rate of more than two yards a year. At Calvados the coast is eroded at the rate of nine or ten inches annually, while on the coast of Seine Inférieur the annual erosion is about a foot. The island of Heligoland, in the North Sea, once a fertile island of considerable extent, has melted away in the sea like a lump of sugar, till now it is little more than a rock. The shores of Hanover, Friesland and Holland were steadily gnawed and nibbled away for sixteen hundred years, and at times there were sudden irruptions of the sea. One irruption in the twelfth century formed the Zuyder Zee, another in the thirteenth century made the gulf of Jahde. In 1230 an inundation of Friesland drowned a hundred thousand men. In 1277 the gulf of Dollart was made. In 1288 the Zuyder Zee overflowed and drowned 80,000 people. In 1421 seventy-two villages were submerged. And now further encroachments of the sea are prevented only by dykes and sea works.



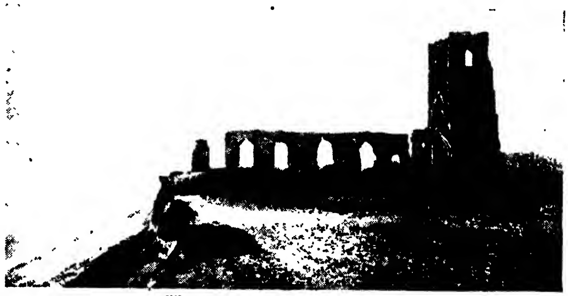
THE WAVE-RESISTING POWER OF ROCKS—A CONTRAST
This huge boulder at Porthleven, Cornwall, is formed of a hard form of gneiss of a type unknown in the rest of Britain. It has not yet been broken up by the force of the waves, though the slate cliffs are receding farther and farther inland.

In England the encroachment of the sea is equally marked, and on many shores "there rolls the deep where grew the tree." But the erosion is not uniform; it depends to a large extent on the prevailing wind and on the geological character of the coast. Geologically speaking, the coast of the British Islands is very complex. Carboniferous limestone, magnesian limestone, shale, clay, sandstone, conglomerate, drift, clays, sands, and gravels and other rocks occur, sometimes in rapid alternation. The chief cliff formations are of limestone, chalk, drift, and sandstone. In Scotland, Ireland, Wales, and in the west and extreme north of England there are cliffs of igneous rock such as granite. These various rocks are eroded by the sea in different degrees. The drift, for instance, is quickly worn away, while the granite offers great resistance. In some cases the sea undermines the soft base of a cliff and causes constant land slips, so that "the whole cliff marches forward like a glacier."

Probably the most serious erosion of the English coast is taking place at the Holderness coast, between Flamborough Head and Spurn Point. Here the average loss is about two to four yards per annum; and it has been estimated that 115 square miles of land have been washed away since the

Roman invasion in 55 B.C. At various times twelve towns and villages have been washed into the sea. The coast consists of drift deposits and boulder clay, which are easily picked to pieces by stormy seas.

The next most serious erosion is taking place along the Suffolk coast, which is periodically nibbled away by heavy seas during north-west gales. To the south of Gorleston, the low cliffs are being washed away at the rate of about one yard per annum. At Pakefield, to the south of Lowestoft, property of the capital value of £12,000 was washed away between 1901 and 1907, and since that date there have been further falls of cliff, together with houses built upon it. At Southwold, Easton Cliff, at its south end, lost 350 feet. At Dunwich, though it may be possible that legend has exaggerated the damage, there is a dismal record of destruction: "monastery, town hall, churches and churchyards, quays, streets, and buildings of all kinds, neighbouring fields and woods, have been swept away piecemeal; and though this place has been continually retreating for safety, a small village, with a single old church, represents a once flourishing town."



The doomed church at Dunwich

The receding land at Pakefield

The falling cliffs at Lowestoft

INROADS OF THE SEA IN EAST ANGLIA

Norfolk is a little more fortunate than Suffolk, but it also has suffered from the assaults of the sea. Roman Cromer is now two miles out to sea. At Sheringham in 1780 there stood a cliff fifty feet high, with houses upon it. Within fifty years cliff and houses were at the bottom of the sea, and over them was water deep enough to float a frigate. The graveyard at Overstrand, the Garden of Sleep of the well-known song, is being gradually eaten away, and will soon sleep under the waves. In Kent, too, active erosion is going on. The three castles at Sandown, Deal, and Walmer were originally built a quarter of a mile from the shore. Now Sandown Castle is beneath the sea, and Deal and Walmer Castles have been saved from a similar fate only by the intervention of sea-walls and groynes. Reculver Church was a mile from the sea in the time of Henry VIII., but in the beginning of last century the churchyard was swept away, and the church would have soon followed had it not been protected by artificial means.

Year by year the white cliffs of Dover are falling away; and ten thousand square yards are said to be in a very insecure condition. Indeed, all round England we find records of erosion. A mile out at sea at Selsey Bill are drowned a cathedral and a palace. Auburn, Hartburn, and Ravenspur are fathoms deep. Under the Goodwin Sands are Earl Goodwin's land; and perhaps the waves round the Cornish coast roll over ancient Lyonesse:

A land of old upheaven from the abyss
By fire, to sink into the abyss again;
Where fragments of forgotten people dwelt.

Between 1848 and 1893 Yorkshire lost 774 acres. Between 1883 and 1905 Lincolnshire lost 400, and Norfolk 339 acres. Between 1879 and 1904 Suffolk lost 518 acres. Between 1842 and 1893 Lancashire lost 545 acres. And, according to Colonel Hellard, late Director-General of the Ordnance Survey, England has lost altogether 4692 acres through erosion during a period of about thirty-five years.

In Scotland and Ireland, where the rocks are harder, erosion is much less rapid; and in the same period Scotland has lost only 815 acres of land, and Ireland 1132 acres.

How the Ruins of the Land are Piled up to Protect the Land

The best defence against erosion seems to be shingle beaches, and often the coast may be best protected by assisting Nature to make such beaches. Let us see what is known about beaches, and what can be done to assist their formation. Beaches are always formed of the débris of the land. The waves and tides that break down the land drop a burden of débris as they run up and down the shore, and the biggest stones are cast highest upon the beach, where they act as a kind of breakwater. Shingle borne and deposited in this way may form very effective protective banks. Off the coast near Cromer there is a famous stone-bed consisting of unworn flints on bare chalk, and most of the coastline is defended by some amount of beach. In most cases, however, the beach defence is liable to be carried away by stormy seas, and in all cases there is a tendency for the beach material to travel in certain directions. Along the East Coast of England the beach material drifts southwards, along the South Coast eastward, and along the West Coast northward; and the direction of the drift, as a rule, is determined by the direction of the prevailing winds.

The Building Up of Protective Beaches by Well-Placed Groynes

In some cases the drifted shingle forms long shingle ridges. At Dungeness there is an accumulation of shingle which "extends out from the shore seawards as an ever-increasing promontory, the base of which measures approximately six miles, the distance from the base to the apex being three miles." Another famous accumulation of shingle, the so-called Chesil bank, extends from Bridport to the Isle of Portland, a distance of eighteen miles. Where it terminates it stands 42 feet 9 inches above high-water mark.

In order to protect the coast, attempts are constantly being made to favour the accumulation of drifted shingle, at any point threatened with erosion, by means of groynes and rows of faggots. Almost every sea town has its beach disfigured and its sea scenery spoilt by these erections. At Eastbourne there are eighty-one timber groynes, at Hastings nearly a hundred concrete ones. At Walton and Felixstowe there are more than one hundred and twenty groynes. In most cases these groynes have been successful in building up beaches, but in some instances Peter has been robbed to pay Paul; for the result of one place collecting shingle has been to deprive another adjacent place of its fair share. For instance, the trapping of shingle at Hastings has deprived the Pett Level, near Winchelsea, of its fair share; and the timber groynes at Bexhill, again, "have accelerated erosion along the seaboard to the eastward toward Hastings."

Still further, it has been found well to imitate Nature and to compact loose sand and soil by planting of various sea-grasses, such as marrum and lyme grass. The long roots of the grasses hold the sand together, and the blades of grass help to form dunes. Sand-sedge, wild thyme, heather, gorse, tamarisk, and even firs and larches have also been used for the same purpose.

The Sensational Sea Less Destructive than the Unnoticed Rain

It must be noticed that the raggedness of many coast-lines, such as the coast-lines of Norway and the West of Scotland, is not due to the tooth of the wave. The indentations represent mountain valleys which have been submerged under the sea by a subsidence of the land.

There is something very dramatic about the fight between the land and the sea—about the fight between man and the waves for the possession of the foreshore, but it is really not such an important fight as it sometimes appears. When a great cliff falls at Dover, when a putting green of the Cromer golf-course drops into the sea, we are apt to imagine that the sea is voraciously devouring the land; and when we hear that thousands of acres have been washed into the sea we are apt to imagine that the rest will soon follow. But, as a matter of fact, the sea as a rule nibbles away at the land very slowly and ineffectually. "Before the sea," says Geikie, "advancing at the rate of ten feet in a century, could pare off more than a mere marginal strip of land between seventy and eighty miles in breadth, the whole land might be washed into the ocean by atmospheric denudation."

THE WAVE-WORN COAST OF GREAT BRITAIN

THE DEVIL'S FRYING-PAN, CORNWALL

THE LAVA ROCKS OF KINGHORN, FIFE

THE SHARK'S FIN, MANACLE POINT, ST. KEVERN, CORNWALL

A GRANITE HEADLAND, ST. MARY'S, SCILLY

THE OLD CASTLE HEAD, PEMBROKE

A REVOLUTIONIST IN THE CLOISTER

MENDEL IN THE MONASTERY GARDEN WHERE HE WORKED OUT THE LAW OF HEREDITY WHICH IGNORED DURING HIS LIFE, CHANGED THE THOUGHT OF THE WORLD AFTER HIS DEATH

THE REVOLUTION OF MENDEL

The Monk who, Experimenting with the Growth of Peas in the Abbey Garden, Changed the Current of Scientific Thought

THE LIFE AND WORK OF A GREAT MONK

By the irony of fate we now pass from the work and the assured contributions of a veteran master still alive, August Weismann, not to those of some junior contemporary, but to the name of a man who actually died nearly a generation ago, and whose work was done, once and for all, very nearly half a century ago. Yet that work is the foundation for the new era in the study of heredity which is characteristic of our own century, and which was initiated by the rediscovery of the work long done, in the last year of the nineteenth century. It is high time, therefore, that we should acquaint ourselves, as closely as possible, with the name and life-work of Gregor Johann Mendel, who will always be regarded as one of the epoch-makers in the science of life. For no biography of Mendel is in existence, nor collection of letters, nor has any popular account of his life yet been published. Considering the dates of his life and work, and the date of today, and the unparalleled attention which the last half-century has devoted to the very problem on which Mendel shed such light, we may confidently say that this history is without any parallel in the records of science.

A dozen years have now elapsed since the attention of the scientific world was directed to Mendel's long-standing and long-lost paper. The conclusions it contained were fiercely contested by the representatives of scientific orthodoxy at that time; and their authority was such that Mendel's law, as we shall learn to call it, was put down as a mere local phenomenon, a curiosity of certain cases of hybridism, and nothing more. Darwin, who would have still been Darwin had these results been laid before him, was dead, and there were only Darwinians left. Hence the general recognition of Mendelism has been tragically delayed, even after the initial loss of a generation between Mendel's work and its discovery. But the logic of facts has conquered; and the establishment of the Balfour Chair of Genetics at Cambridge may be said to mark the final acceptance of Mendel's work by the academic world. We may therefore try to acquaint ourselves with what personal facts are available regarding one of the now acknowledged masters of science; and to this end we shall be greatly helped by the publications of Professor Bateson, the present leader of the Mendelian school, whose reverence for his master is expressed in his great work "Mendel's Principles of Heredity," unfortunately too large and expensive to be very generally available.

Gregor Johann Mendel was born, the son of a peasant, in Austrian Silesia, on July 22, 1822. Though the name suggests a Jewish origin, he was probably of German stock. His father was interested in plants, and early taught his son the methods of fruit-grafting; and his mother's brother was an educational pioneer, so that there is some evidence of hereditary transmission on both sides in the making of the young Johann, as he was christened, Gregor being his name "in religion," taken when he was admitted to the Augustinian monastery at Brünn, for the purpose of teaching under its auspices. In 1847 Mendel was ordained a priest, and later he was sent to the University of Vienna for two years at the expense of the cloister. Then he returned to Brünn, where he taught for fifteen years in the school. He was a born teacher, like his uncle, enjoyed his work greatly, and had extraordinary success with his pupils. It was especially science that he taught. At the end of this period, in the year 1868, he was elected Abbot of the monastery.

The observation was made, many years ago, that Louis Pasteur was the one and

only man of science of the first rank whom the Roman Catholic Church has contributed to the world since the Reformation. To that illustrious name must now be added the name of the Abbot of Brünn. Even so, the extreme fewness of the Roman Catholic men of science remains as a historical fact worthy of consideration, whatever its interpretation may be. And in Mendel's case, unfortunately, science has to mourn the important position which he filled in the Church, doubtless well and usefully, but not otherwise than many another man, not a Mendel, might have filled it. For everything that his name will live by was done during his fifteen years as a schoolmaster, and the scientific record from 1868 until his death is absolutely blank. Nor was that the whole loss, as we shall see.

The Conditions under which Mendel Carried on His Epoch-Making Work

Most schoolmasters have the advantage of a fair amount of leisure. Mendel loved teaching, and was not exhausted by it. He had energy enough left for the employment and enjoyment of his leisure. He had, also, his interest in plants, partly inherited, no doubt, and partly inculcated in early life by his botanically inclined father; and he had had two years devoted to the study of science before his teaching began. Lastly, he had at his disposal the large garden of the cloister. Even as a novice, before going to the University of Vienna, he had begun experimental work in this garden, which will always be regarded as an historic arena of science. He had introduced various plants into the garden, and watched their behaviour under various kinds of treatment, and it was his pleasure to show these cultures to his friends. While he was quietly working away under these conditions, for his own pleasure, and without thought of controversy or publication, or of the bearing of his observations upon anything so colossal and unmonastic—shall we say?—as the theory of organic evolution, Darwin published the "Origin of Species" in London in 1859.

How Mendel Knew of Darwin, though Darwin Did Not Know of His Contemporary

The whole world was at once filled with the noise of it. There was a Philosophical Society at Brünn, to which Mendel belonged, and thus, from the very first, Mendel was acquainted with Darwin's name and Darwin's work, whereas Darwin died without ever having heard of Mendel. From the first Mendel was in disagreement with the fundamental theory of Darwin that species take their origin in the selection and perpetuation of minute random variations that are inherited by the offspring. Thus it is recorded that on one occasion, when showing his garden to a scientific friend, and noting how two species had been cultivated side by side for some years without showing any change, Mendel jokingly said: "This much I *do* see—that Nature cannot get on further with species-making in *this* way. There must be something more behind." Indeed, it seems to have been the publication of Darwin's views that caused Mendel to persist in his experiments with peas, which he continued for a period of eight years. Nothing can now be more obvious than what the Darwinian view immediately required was experiment in order to test it. Everything else—argument, theory, vituperation, controversy, reference to the observed facts of natural history—all these Darwinism received, but not experimental breeding. Mendel, however, the man of genius, saw instantly that that was what was required, and now we all agree with him. He communicated his results to the Brünn Society in 1865, 1866, and 1869, but they all passed unheeded.

An Ecclesiastical Promotion that Impoverished the Scientific World

His cardinal work, as we already know, was done upon peas. But he also studied bees, a purpose for which the large monastery garden was very suitable. He actually had fifty hives under observation. On this part of his work Professor Bateson writes as follows: "He collected queens of all obtainable races—European, Egyptian, and American—and effected numerous crosses between these races, though it is known that he had many failures. Attempts were made to induce the queens to mate in his room, which he netted in with gauze for the purpose, but it was too small or too dark, and these efforts were unsuccessful. We would give much to know what results he obtained. In view of their genetic pecularities, a knowledge of heredity in bees would manifestly be of great value. The notes which he is known to have made on these experiments cannot be found; and it is supposed by some that in the depression which he suffered before his death they were destroyed."

This is a very serious loss to science. Years of faithful work, done by this highly gifted investigator, are wasted. The hives which he used still stand in their places, but the notebooks are gone. Very likely more than half of all the work he did is thus lost.

But indeed, considering his opportunities and energies, and length of life, his total sum of scientific work was very small in bulk. The fatal day for science was that on which Mendel was elected Abbot. There his researches ended. He himself hoped otherwise, expecting that after a time he would be able to do more scientific research than before. But, unfortunately, certain taxes were now imposed by the Government on the property of religious houses, and these, which Mendel conceived to be unjust—and which were, in fact, removed a few years after his death—he refused to pay. He became a "passive resister," and so remained alone, even after other monasteries, with him at first, had given in. All his time was spent over this deplorable business and the legislation which it involved. Nothing would move him, even though the property of the monastery was ultimately distrained upon. He fell ill, and the last ten years of his life were passed in disappointment and bitterness. He had been cheerful and companionable, but now became misanthropic and depressed. On January 6, 1884, two years after Darwin, he died.

The Strange Neglect of the Work of Mendel While He Lived

All this time, of course, the controversy was raging over Darwinism. Far and away the worst result of all this litigation and diversion of Mendel from the special interests for which his mind was formed was that he never joined in the controversy, and never even wrote a letter to Charles Darwin, who would most certainly have been grateful for it to the end of his days. The whole progress of biology, and the possibility of framing a true theory to explain organic evolution, have been delayed by decades in consequence. We are now only where our predecessors should have been, say, in 1878. It seems not to be true, however, that Mendel had lost interest in his own researches, and did not care what happened to them. Apparently he had no time to do anything on his own account, though to send a copy of his paper to Darwin would not have taken very long. But he was seriously disappointed that his work should have been neglected. He is reported to have believed in its future, as well he might, and to have been in the habit of saying: "My time will come!"

Why it did not come as and when it should have done will apparently be somewhat of a puzzle always. The history of science has many examples of cases where great discoveries have been despised, though there must be few, if any, "in which the discovery so long neglected was at once so significant, so simple, and withal so easy to verify." It seems to have been accident in this case, but it will always remain inexplicable that Mendel's work, appearing as it did when several naturalists of the first rank were occupied with these problems, should have passed wholly unnoticed, though we know that the Brünn Society exchanged its publications with most of the learned Societies of Europe, including our own Royal Society and Linnæan Society. Darwin may have turned over the very issue in which Mendel's paper first appeared, while he was looking for something else.

How Darwin's Theories Had Lured Men Away from Experimental Research

Mendel himself seems to have failed to interest one distinguished contemporary, and made no further attempts, though it would not have been Darwin's way to neglect new truths—the Darwin who had received Dr. Alfred Russel Wallace's paper from the other side of the world a few years before.

Professor Bateson has doubtless put his finger upon the most profound cause of the neglect of Mendel's work for a generation. It was "that neglect of the experimental study of the problem of species which supervened on the general acceptance of the Darwinian doctrines." Until that time, many men were working on the species problem by experimental crossing, as Mendel did. But now new workers were not forthcoming. No one felt much interest in the matter, because Darwin's views had turned the attention of all biologists in other directions—the "struggle for existence," "natural selection," "adaptation," "spontaneous variations," and so forth. Also, Darwin strongly believed that "Nature does nothing by jumps," and that the result of crossing could be totally left out of account in the problem of species formation. Thus the tedious methods of experimental breeding—which, further, were supposed to have yielded no definite results—fell out of fashion.

Unfortunate Mistakes which Partly Neutralised the Discoveries of Great Men

It was a very great pity, but it has its lesson for us, of course, and also a notable parallel in another branch of science. In the physical sciences Newton was, by universal consent, the greatest man who ever lived. Like all men, including the greatest, he made mistakes, the real value of a man not being measured against his

mistakes, but by the quality and extent of his successes. Newton made great contributions to optics, above all in his discovery of the compound nature of white light by means of the prism. But he strongly advocated the "corpuscular theory" of light, according to which light consisted of a stream of separate particles, or corpuscles. It is the historical fact that this erroneous theory, having the authority of Newton's name—though no one's name affects the truth of things—retarded the progress of optics for decades. And just similarly it now appears that Darwin's authority retarded for decades our knowledge of those fundamental facts of heredity upon which any true theory of the "origin of species" will some day depend.

Mendel's Repudiation of the Distinction Made Between Varieties and Species

So much for Mendel himself. Let us now turn to his paper, "Experiments in Plant Hybridisation," upon which his title to fame rests. It was read before the Brünn Society in 1865; alas that it was not then read before the Royal Society! "Hybrid" was a term used by Mendel for the offspring of two varieties, we must note, though the term is often restricted to the offspring of two distinct *species*. Mendel himself held that this difference between varieties and species is only a question of degree, and he was quite content, therefore, to use the term "hybrid" for the offspring of two varieties, and to speak of his experiments as "hybridisation." Unfortunately, when his work was rediscovered, many critics argued as if it dealt with the crossing of distinct species, producing such hybrids, in the stricter sense, as the mule; and as such hybrids are commonly sterile, though that view must now be qualified, it was argued that the Mendelian observations could have no bearing on the formation of new species. We here note, then, that in point of fact his work was done with varieties of a single species, though he happens to call it "hybridisation," and that today we are bound, by his own work and that of his followers, to agree with him that the distinction between varieties and species is not even a real one in any case.

An Attempt to do a Complete Work in a Small Field

The paper will always be one of the classics of biology; and as it is as yet practically inaccessible to the ordinary reader, we may look at it with some care. In his preliminary remarks the author writes as follows:

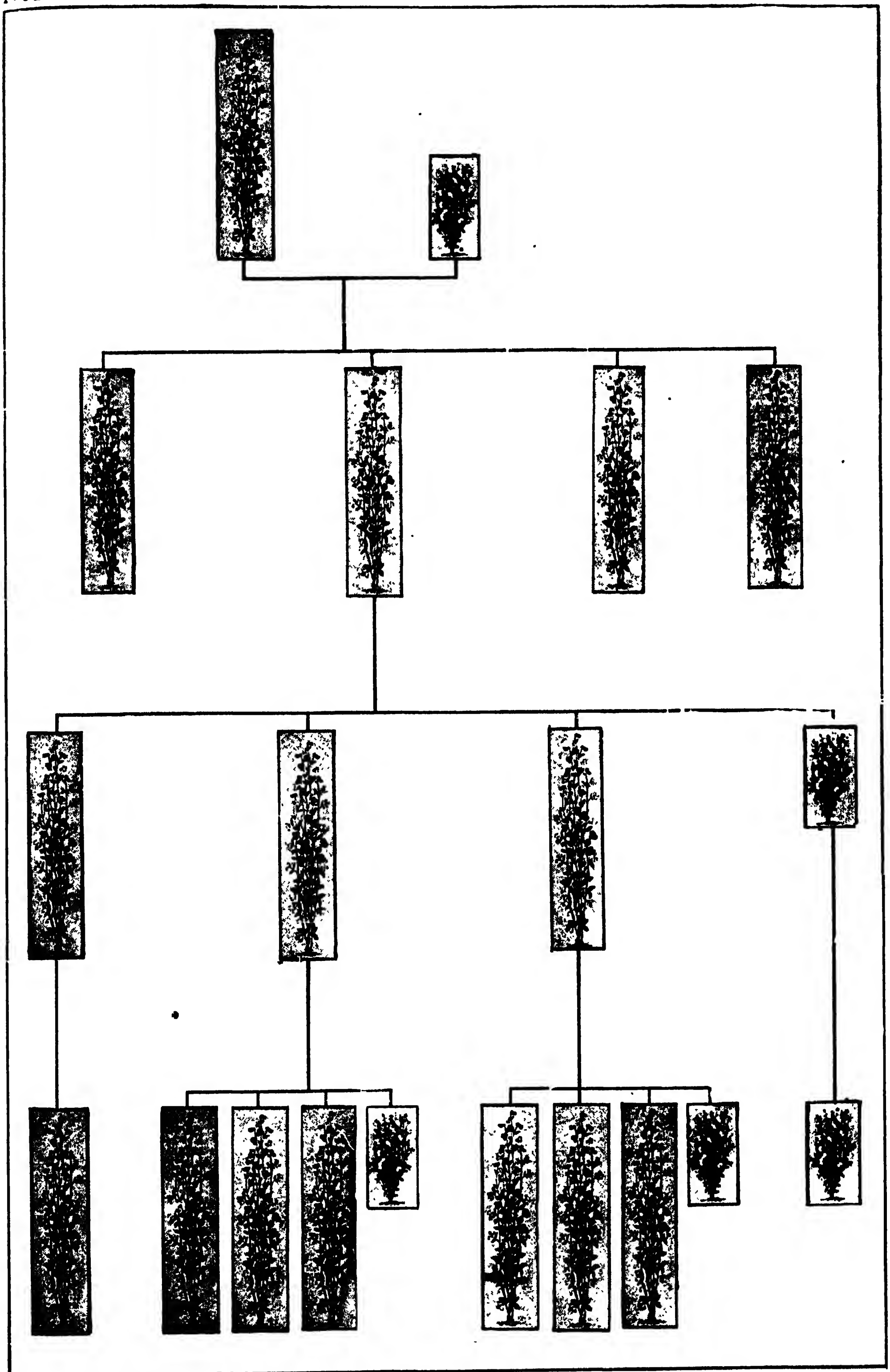
"Those who survey the work done in this department will arrive at the conviction that, among all the numerous experiments made, not one has been carried out to such an extent and in such a way as to make it possible to determine the number of different forms under which the offspring of hybrids appear, or to arrange these forms with certainty according to their separate generations, or definitely to ascertain their statistical relations. It requires, indeed, some courage to undertake a labour of such far-reaching extent; this appears, however, to be the only right way by which we can finally reach the solution of a question the importance of which cannot be over-estimated in connection with the history of the evolution of organic forms. The paper now presented records the results of such a detailed experiment. This experiment was practically confined to a small plant group, and is now, after eight years' pursuit, concluded in all essentials."

Of course, the facts had been waiting for ages to be ascertained; but though they would certainly reveal themselves automatically on certain conditions, they could never be recognised otherwise.

Mendel's Proof that a Study of only Two Generations is Practically of No Account

Mendel realised those conditions clearly, as none of his predecessors did, and they were the condition of his success. He describes them in the foregoing passage. The three primary necessities were to discover the number of forms under which the offspring of hybrids appear, to keep the successive generations sharply distinct, and to discover the numerical proportions between the various forms obtained. Many of Mendel's predecessors had performed hybridisation experiments, observing what forms the hybrids took when different species or varieties were crossed. We now see, after the event, what Mendel saw before it—that such experiments have only been begun, and that we can reach no conclusions from them until we have mated the hybrids among themselves, and have determined "the number of different forms under which the *offspring of hybrids* appear." Thus, if Mendel showed anything, it was that our study of heredity can never be brought to true conclusions by means of observations or experiments upon two successive generations alone. At the very least, we must have three generations to compare; and all the statistical and other work on heredity, before Mendel's time and since, which only compares parents and offspring, has to be

MENDEL'S EXPERIMENTS WITH THE PEA



A PICTURE-DIAGRAM OF THE RESULTS OF CROSSING TALL PEAS WITH DWARF PEAS

left finally on one side. We see now that it can teach us nothing.

The plant which Mendel chose for his observations was the ordinary edible pea, *Pisum sativum*. It was a happy choice in the comment it would furnish on the familiar phrase "as like as two peas," for no one acquainted with Mendelism can ever use that phrase again without reflecting how much more there is in "two peas" than meets the eye. But Mendel chose the pea because its varieties are sharply marked in various definite respects, and because it was possible to protect the hybrids, during their flowering period, from the influence of all foreign pollen.

Mendel's Choice of the Pea for Study, and Why the Choice was Made

This is of cardinal importance; and neglect of it has prevented the revelation of Mendel's law in many experiments made before his day and after it, for, as he said himself: "Accidental impregnation by foreign pollen, if it occurred during the experiments, and were not recognised, would lead to entirely erroneous conclusions."

Mendel studied thirty-four more or less distinct varieties of peas, with regard to the hereditary transmission of a number of characters, such as the form of the seeds, their colour, the position of the flowers, and also the length of the stem. This last was particularly striking, for it was possible to cross plants with a stem of six to seven feet with dwarf plants averaging only one foot high. In all, he studied seven distinct characters; and the first result he obtained, in each case, was one which hybridisation experiments had frequently shown before. This result was the absence of what is sometimes called "blended inheritance." It seems reasonable to suppose, for instance, that the hybrid offspring of two plants, one six feet and the other one foot high, would "strike an average" between the parents. But this never happened; the offspring of these crosses were always as tall as the tall parent. We shall see in due course what happened to *their* offspring.

Mendel's Argument that Blended Inheritance Really Does Not Happen

Meanwhile, we note this initial fact, a cardinal idea of Mendelism, that so-called "blended inheritance" really does not happen. We may often see, in human beings and elsewhere, what looks like blended inheritance, and the assumption by the offspring of a sort of compromise between two markedly different parents. But probably every one of these cases is due to faulty analysis on our part. Either we are confounding mere fluctuations, due to varying nurture, with natural, hereditary, genetic characters, as the biometricians did, or else we are dealing with characteristics due to a great number of different factors, all intertangled, of which we are not yet able to trace the transmission separately.

Now, in all Mendel's experiments, one of the pair of contrasted characters, represented in the individuals he was crossing, appeared in *all* the offspring, while the opposite disappeared. Hence his new terms, introduced by himself as follows: "Henceforth in this paper those characters which are transmitted entire . . . and therefore in themselves constitute the characters of the hybrid, are termed the *dominant*, and those which become latent in the process *recessive*. The expression 'recessive' has been chosen because the characters thereby designated withdraw or entirely disappear in the hybrids, but nevertheless reappear unchanged in their progeny, as will be demonstrated later on. It was furthermore demonstrated by the whole of the experiments that it is perfectly immaterial whether the dominant character belong to the seed-bearer or to the pollen-parent; the form of the hybrid remains identical in both cases."

Mendel's Theory of the Grouping of Hybrid Characters into Dominant and Recessive

The generation of hybrids thus described is known as the first filial generation, or, in the modern terminology of genetics, the F 1 generation. Its characteristics establish the idea of dominance and recessiveness, of which we shall hear so much hereafter. The writer remembers hearing Sir Francis Galton—who freely accepted this discovery of Mendel, unlike many of his followers—regret that the pair of words employed by Mendel were not *dominant* and *recedent*, which would be better from the literary point of view. We may also speak of them, if we will, as *patent* and *latent*. But it is particularly to be observed that we have no right to speak of the character which does not appear as being recessive or latent, so long as we study only the F 1 generation. So far as that generation is concerned, the shortness, for instance, of the short parent is simply not transmitted; there is no sign of it in any of the offspring. How many acres of waste-paper must we regret, filled with calculations and assertions as to, say, the non-transmission of such and such a character, on the ground that the offspring of the parent who

displayed it are found to show no trace of it at all!

Only when the individual hybrids of the F 1 generation are bred from do we discover the truth, which is that the characters of which no vestige appeared in the F 1 generation were not, therefore, necessarily lost. For in the F 2 generation—*i.e.*, in the offspring of the hybrids—the recessive characters reappear. Here is the memorable paragraph from Mendel's own paper, in which his epoch-making discovery is stated: "In this generation there reappear, together with the dominant characters, also the recessive ones with their peculiarities fully developed, and this occurs in the definitely expressed average proportion of three to one, so that among each four plants of this generation three display the dominant character and one the recessive. This relates, without exception, to all the characters which were investigated in the experiments. The angular wrinkled form of the seed, the green colour of the albumen, the white colour of the seed-coats and the flowers, the constrictions of the pods, the yellow colour of the unripe pod, of the stalk, of the calyx, and of the leaf venation, the umbel-like form of the inflorescence, and the dwarfed stem, all reappear in the numerical proportions given, without any essential alteration. *Transitional forms were not observed in any experiment.*"

The Curious Results in the Second Generation of Mendel's Crossings

That, of course, was an extremely remarkable and unheard-of result to obtain. The tall and the short, for instance, when crossed, yielded an F 1 generation all tall. But the offspring of these tall hybrids persistently came out in the ratio of three talls to one short. These facts of the F 2 generation, the offspring of the hybrids, still further disposed of the view that inheritance is blended. It was evident, on the contrary, that something which involved tallness, and something which involved shortness, could go into a new individual, or fail to go, or even that both might go, as in the hybrids of the F 1 generation; yet they did not blend with each other even then, but separated or "segregated" again, as was proved by the tallness or shortness of the individuals of the F 2 generation, who were just as sharply contrasted as their grandparents had been.

Now, the student must be patient, for this is not all, and the mind is very apt to become confused. This definite ratio of, for instance, three talls to one short in the F 2 generation must mean something; and Mendel naturally had recourse to what we now recognise as the one method of finding out the real structure of individuals. He bred from them, with most notable results. The shorts remained short in their offspring, and in theirs and theirs indefinitely. Evidently the tallness had been clean bred out of them, notwithstanding their parentage. Thus, we observe, in such a case it was possible at once to extract a short race, which bred true, from tall parents. This would be a mystery indeed did we not know what the parentage of those tall parents had been.

The Effects Brought Out in a Third Generation by Crossings

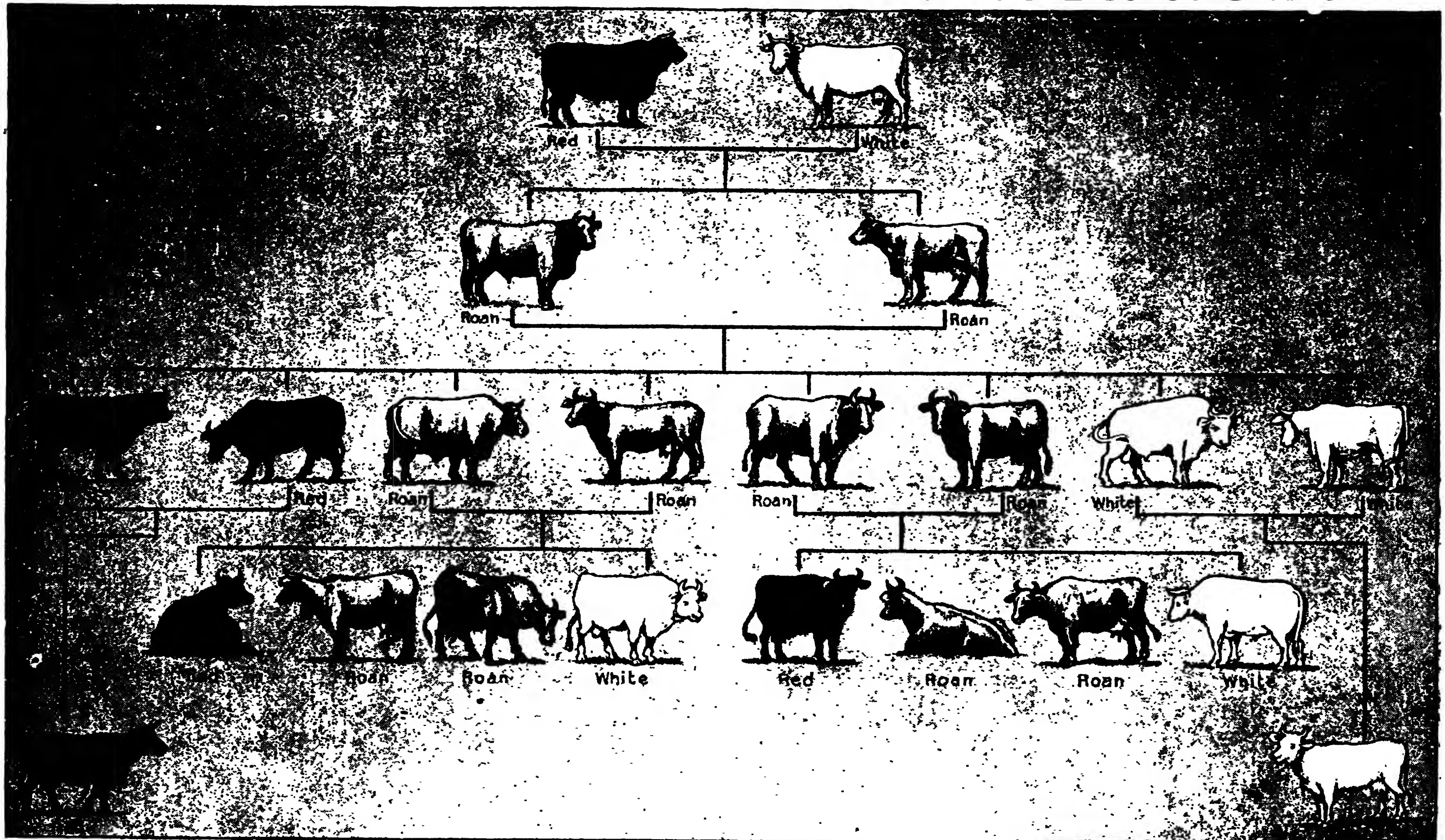
But now consider the three-fourths of the F 2 generation, which were tall. All alike possessed the dominant character, which was seen in their parents, and in one of their grandparents. But when they are analysed, by the unique Mendelian method, which is that of breeding from them, it is found that they are not really all alike in their genetic constitution. One-third of them yield talls, and those talls yield only talls, and so on. This third of the tall three-fourths thus compare and contrast with the remaining fourth, which were short. In each of these fourths of the F 2 generation the hybrid character has been completely separated, so that the one-fourth is purely tall and will yield nothing but talls for ever, while the other fourth is purely short.

As for the remaining two-thirds of the three-fourths that were tall, they are just like their hybrid parents, and their offspring come out again in the ratio of three talls to one short, just as before.

The Results Showing that Variation Depends on the Composition of the Germ-Cells

What this all means we must let Mendel himself state: "It is now clear that the hybrids form seeds having one or other of the two differentiating characters, and of these one-half develop again the hybrid form, while the other half yield plants which remain constant and receive the dominant or the recessive characters (respectively) in equal numbers." Later on, he states the same conclusion in slightly different words: "The offspring of the hybrids of each pair of differentiating characters are, one-half, hybrid again, while the other half are constant in equal proportions, having the characters of the seed and pollen parents respectively."

A PICTURE-DIAGRAM OF MENDEL'S LAW AS EXEMPLIFIED IN THE COLOURS OF CATTLE



If pure red and pure white cattle whose colours are of equal potency are bred together, the results shown in the above picture may be expected in the subsequent generations. The Mendelian explanation is that the roan hybrid carries from the beginning all the sex-cells which will decide the colour, and carries them in a pure and not a blended condition, these cells being produced in approximately equal proportions.

Any reader who has not previously studied the results of Mendel will probably be content at this point that we should not follow the complications which ensue when we observe various combinations of characters, instead of simply studying contrasted pairs, one at a time. But already the results, as stated above, suffice for a conclusion. These ratios, their definite character, and their definite behaviour in successive generations, must clearly depend upon the composition of the germ-cells, or gametes, as we now call them, which are formed in the various types of individuals that we have studied.

Mendel's Conclusion Respecting the Production of Constant Forms from Hybrid Plants

Thus, when Mendel had described in detail all the results of his experiments, of which the essential part has been given above, he proceeded to the concluding portion of this wonderful paper, headed "The Reproductive Cells of the Hybrids." He clearly saw that the facts of breeding, ascertained by himself, led to certain definite conclusions as to the gametes. He says – and we must count it a privilege to quote "Mendel's law" in the exact words in which it was first enunciated—that: "So far as experience goes, we find it in every case confirmed that constant progeny can only be formed when the egg-cells and the fertilising pollen are of like character, so that both are provided with the material for making quite similar individuals, as is the case with the normal fertilisation of pure species. We must therefore regard it as certain that exactly similar factors must be at work also in the production of the constant forms from the hybrid plants. . . . The conclusion appears logical that in the ovaries of the hybrids there are formed *as many sorts* of egg-cells, and in the anthers *as many sorts* of pollen-cells, as there are possible combination forms."

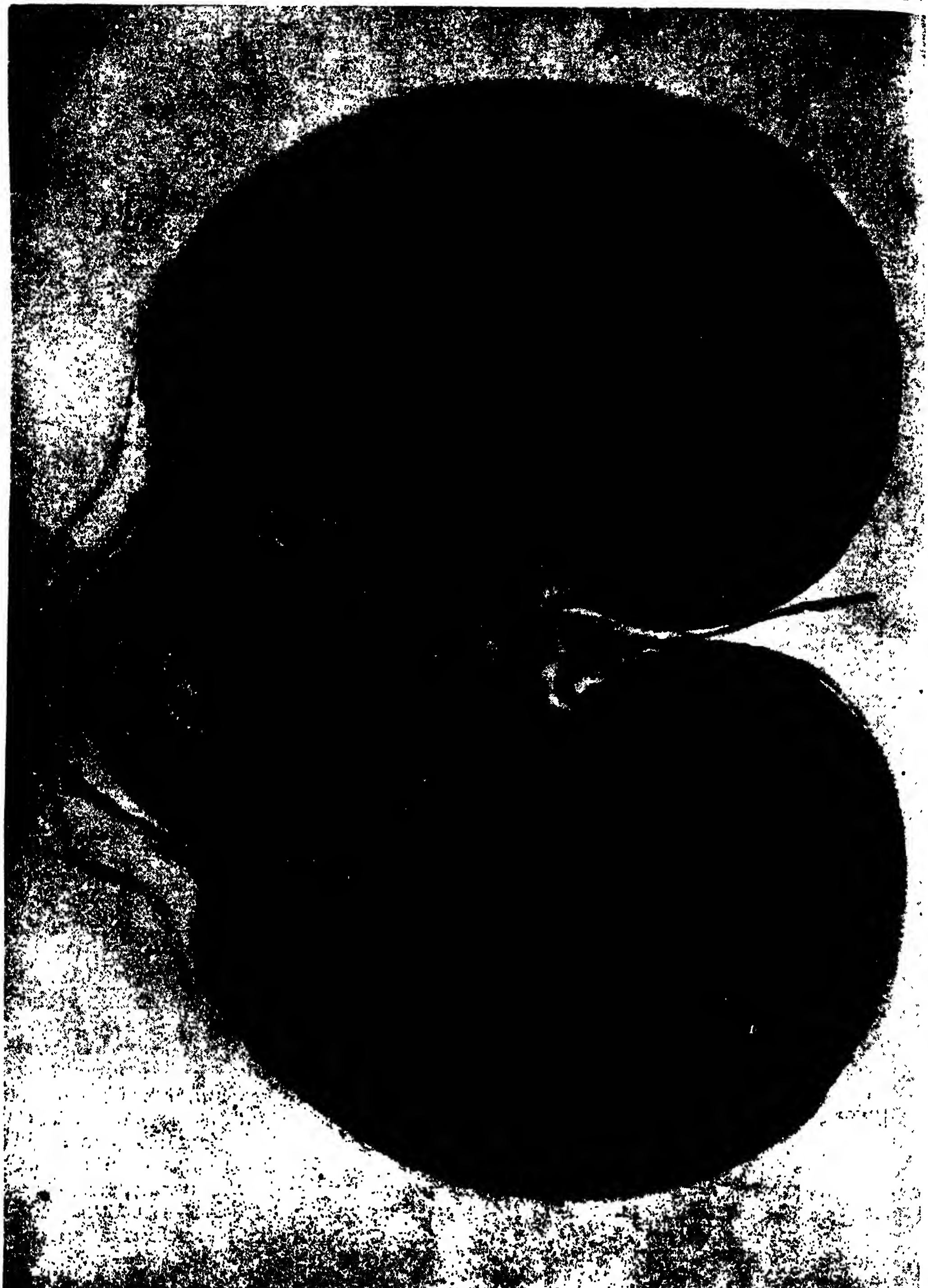
A Summary of Mendel's Essential Ideas that Preceded Weismann

And thus the characters and the proportions of the individuals formed in successive generations, as we have seen, can be completely accounted for "if we assume that the various kinds of egg and pollen cells were formed in the hybrids on the average in equal numbers." And here, finally, is the paragraph which ends Mendel's paper, but for a supplementary section referring to other species of plants. This paragraph contains Mendel's law of segregation: "The law of combination of different characters which governs the development of the hybrids finds, therefore, its explanation and foundation in the principle enunciated, that the hybrids produce egg-cells and pollen-cells which in equal numbers represent all constant forms which result from the combinations of the characters brought together in fertilisation."

So much for our study at first-hand of this classical contribution to biology. It will be much clearer when we come to discuss it for ourselves, but what took the author eight years to discover we need not grudge half an hour to decipher. The foregoing excerpts from Mendel's paper contain the essential ideas (enunciated long before Weismann's theory of determinants, which we have already studied), first, that the characteristics of the individual are due to some kind of entities, "factors" or "determinants," existing in the germ-cells from which the individual is developed; second, that these factors are distributed in the germ-cells according to the laws of chance; third, that opposite factors, meeting in a germ-cell, would not blend, but segregate; and fourth, that when opposite factors meet, one tends to be dominant and the other recessive. As to the interpretation of this last fact we shall see later.

An Indispensable Pioneer who Died in Depression and Obscurity

Here, however, we may leave Mendel and his work. But for the inclusion of his name in a bibliographical list, which ultimately led to the rediscovery of his paper, the records and controversies of science were silent about him until Darwin had been dead for eighteen and he for sixteen years. Then, in 1900, thirty-five years after his work was completed, there appeared independently, but within a few weeks of each other, the three papers of the botanists De Vries, Correns, and Tschermak, each of whom confirmed and extended Mendel's conclusions. With that date begins the modern era in the study of heredity; and having paid homage to the memory and work of the indispensable pioneer, who was without honour in his lifetime, and died in depression and obscurity, and who would incalculably have altered his own latter years and the course of science if he had scribbled a note to Darwin, we must pass on to the more minute study of what his followers have now established. The path is not easy, but we have the sure clue of "Mendel's law," and there is no limit to the control of life and the creative possibilities that may lie at the end of it.



This highly magnified photograph of a section through a grain of wheat shows the large proportion that is devoted to the storage of food for the germ, which is on the left, with the cells that will go to form the leaves wrapped round each other in the manner characteristic of the wheat-shoots when they appear above the soil. The diagram on page 2128 indicates the names of the parts to be seen.

This photograph and those on pages 2130, 2131, and 2132 are by Mr. J. J. Ward. The others are by Messrs. Hinkins & Son

PLANTS AS STOREHOUSES

How Plants, by Garnering Rich Foodstuffs for Their Own Progeny, Feed Mankind

WHERE PLANT-FOOD IS ACCUMULATED

The search for food must ever be a problem of vital importance to living organisms, but it becomes a most urgent need, in the case of plants especially, as compared with animals, inasmuch as the former are not endowed with the means of locomotion. Their area of food supply is limited; and it therefore is of the more importance that there should be some means devised by which the plant can store up for itself its own nutrition over and above that required for present needs. Not only is storage of food required for the plant itself, but it is essential to the embryos of the plant, for, as compared with animals again, they are still more dependent upon some sort of provision for nourishment in their earliest stages.

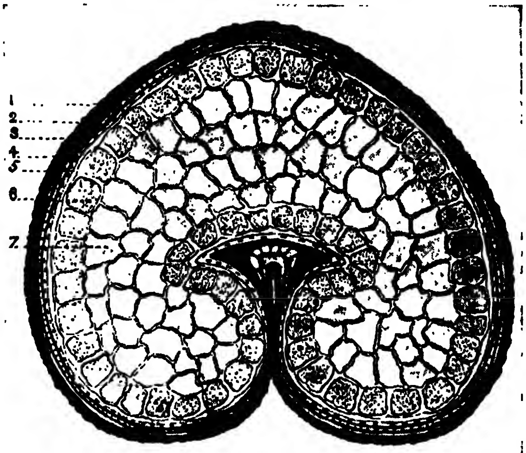
In our last chapter we saw that in the class of plants to which the bean belonged there is ample provision made for the nourishment of the young embryo in the seed-leaves, or cotyledons; and these structures play such an important part in the question of the storage of plant food that we must devote some little further attention to them. As we shall see, they are by no means all like those we have studied in the bean.

Their function, in the first place, is to provide the primary axis, or embryonic stem, with food. This primary stem, it will be remembered, consisted of the radicle, which grew definitely downwards, and the plumule, growing as definitely upwards. Neither of them at first is capable of getting food for itself, though in the course of time the radicle will throw out root-hairs, and will otherwise develop its capacity as a food-searcher, while the plumule will grow into the stem, and develop leaves that will bear their part also in the general life and nutrition. All this, however, is in the future, and in the meantime food there must be for the growth of these organs. Now, so long as the radicle and the embryonic stem are enveloped within the seed-coat, and, indeed, for some time afterwards, they are functionless, in so far as they cannot absorb inorganic foodstuffs from the soil, and are also utterly incapable of transforming these into organic compounds. Nevertheless, as we saw in studying the processes of nutrition, both organic and inorganic substances are required for growth. Not until the radicle has become a root in the true sense of the term, and not until true green leaves have developed from the stem, can the nourishment of the young plant be said to be independent. Until that stage is reached, life is dependent upon previously stored nutrition; food that has been assimilated and carefully deposited within the seed; food derived from the maternal plant; substances which, as regards their actual nature, are composed of starch, fat, and proteids, all carefully guarded for the benefit of the embryo.

The storage chambers are, in most cases, the cotyledons. In their cells this supply of reserve material has been packed away until the needs of the growing embryo have made themselves felt. Without them the radicle and the stem would fail to grow, as can be proved by cutting away the cotyledons, when these two structures die from starvation. Special storehouses besides the cotyledons are sometimes formed within the seed-coat, and these, too, contain similar starches, and fats, and proteids, the whole forming the endosperm.

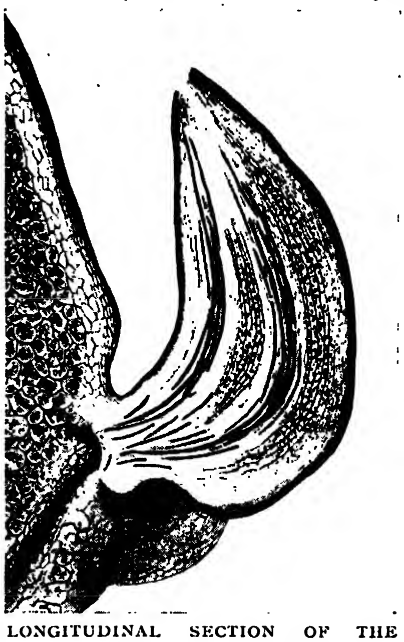
When the germination begins in such a condition, the two cotyledons are seen to increase in length, and to come into contact with this reserve store of food; and it would appear that their function in this case is a special one in connection with absorption. They stand in the position of

the middleman in reference to the consumer. They, in the first instance, take up the stored food elements which have been themselves dissolved in the reserve tissue. This dissolving is also sometimes due to the cotyledons themselves. Then the cotyledons act as distributors, taking away the organic compounds from the storage area. It sometimes happens that only a portion of the cotyledons is enabled to act as an absorber of this food, as is the case in the onion, where the special cells required for this purpose are only developed at the end of the cotyledons. In this plant, after the cotyledon has absorbed the stored-up food by means of its own apex, it leaves the cavity of the seed-coat, and assumes a green character, acting in the same way that an ordinary leaf does. Here we have a bulb which has arranged on its stem a number of thick, fleshy, folds, or leaves, lying over each other. The bases of these leaves form the main bulk of what is usually spoken of as the onion, the leaves thinning out as they reach the stem. After the full growth is over in summer, the green portions wither away, and their inferior parts form a protection for the rest of the bulb.



TRANSVERSE SECTION THROUGH A GRAIN OF WHEAT
1, Epicarp; 2, mesocarp; 3, endocarp; 4, testa; 5, seed-coat; 6, cells containing aleurone grains; 7, cells containing starch grains.

Should such a bulb be kept until the succeeding year, and then planted again, it forms a new set of roots, produces leaves, and an inflorescence which is familiar to all of us when an onion is going to seed. Now, this second growth is dependent for its food supply upon the nourishment stored away in the bulb scales. All this nourishment is used up when the flowering stem is produced; and when the seeds have become ripe, the plant, having nothing more to live upon, dies. The first onion was an annual; the second one, a biennial. Sometimes, however, there is no inflorescence formed, but merely shoots like leaves, which themselves form small bulbs, just as an onion seedling does; and these small bulbs are available for perpetuating the life of the plant after the parent plant has died down. In this case the onion becomes a perennial. This variation in the growth of the onion plant, made possible as it is by the different methods of storage, and the variety of storage organs, introduces us to the terms annuals, biennials, and perennials, in connection with plant life, and these must be clearly understood before we proceed further.


LONGITUDINAL SECTION OF THE GROWING EYE OF A POTATO

An annual plant is one which germinates, grows, and finishes its processes of flowering and fruiting within the limits of one single year, and it dies away if its seeds become ripe. That being the case, it is not surprising that annual plants concentrate their energies on the production of large quantities of seed. The largest annual plants are found in the castor oil group, and in some of the balsams. Usually the whole season, from spring to autumn, is required for an annual to produce its seed, though some of them, of which the common groundsel is an example, produces seed in a few weeks, and may even produce a second and third crop in one season.

Biennial plants are those which, beginning as seedlings in one season, produce during that season only roots, stem, and leaves, but not either flowers or seeds. They then undergo a rest stage during the winter, resuming growth in the following spring

and now develop a stem which in this second season bears both flowers and seeds; and when the latter have reached a condition of ripeness the plant dies. Since the process takes two years, the plant is termed biennial. The parsnip is an example of this.

Plants requiring more than two years before they produce flowers and seeds, or that live as individuals for a period of more than two years, are termed perennials.

The question of the annual, biennial, and perennial habit of life amongst plants is very intimately connected with the problem of the storage of nutrition we are at present considering. It is obvious that if a plant dies down at the end of a summer season, and reappears the following spring as the same individual plant, but with new stems and leaves, there must be some sort of provision for the maintenance of its life during the intervening months. In other words, it must have had some method of storing up sufficient food to keep itself alive. This material is the surplus organic foodstuffs made by the plant, and deposited in one or other structure or part of itself where it can be utilised at some future time. If the plant be an annual, this reserve food is stored up in the seeds alone, where, as we have seen, it is utilised by the next generation in the process of germinating. In the case of wheat and other cereal plants, the seed becomes filled with this reserve store of food, termed the endosperm. In many other annuals, as in the case of the pea and the bean, the storage is looked after by the cotyledons.

To a certain extent the same thing happens in the case of biennials and perennials; that is to say, in plants of these types there is also a certain amount of reserve surplus food stored up in seeds. But a biennial plant, and also a perennial one, does more than this, because before it comes to the end of the growth of a spring and summer, it has collected and stored away a considerable amount of organic material in different parts of its structure. It is upon this surplus store of food the plant calls for its nourishment in the first part of the following spring, when life and growth become once more obvious to the eye of the least observant.

BEAN PLANT AFTER GROWTH OF ROOT AND DEVELOPMENT OF TRUE LEAVES

Other familiar plants offer many examples of various devices for the storage of food. One very common arrangement is to be found in certain roots, such as those of turnips and carrots, whose roots contain the surplus food. We have seen that the onion and similar plants, such as tulips, etc., keep a store of food in the thick bulb scales. A still more familiar example is the tuberous root of the potato. In hops the storage is in the peculiar roots of the plant, while in most of our trees and shrubs the reserve food is stored during the winter in the cells of the stem itself.

The next question is: What are the actual substances or materials thus stored away as reserve food? They are different organic compounds built up by the activity of the cell protoplasm of the plant, particularly a group of compounds which we know as proteids. Green plants, while they are growing, build up sugars and other carbohydrates, the nitrogen required for the production of these substances coming from either the atmosphere or the salts in the soil. Some of these sugars and fats are consumed in the early stages of the growth of seeds and bulbs; most of the sugars, fats, and proteids, which the plant makes for itself, are used to build up its own protoplasm, and its own cell-walls at the parts

where the plant is growing. But if the environment of the plant be satisfactory, and such that active growth is taking place, there is more organic material produced than the plant itself needs for its own immediate use, and this it is which is stored up in the different ways we have mentioned. In most plants these reserves of food are in an insoluble condition, simply because they would require too much space were they to be stored in solution.

Of all these reserve foods, starch is one of the commonest. It consists of very small grains, made of several layers of the same substance, arranged round a definite point. This starch is in great abundance in roots and tubers, as well as seeds, and it forms no less than from 50 to 70 per cent. of cereal grains, while in the case of potatoes from 10 to 30 per cent. of the total bulk is composed of starch. The granules of starch are not always of the same kind, and some of them are quite distinctive of the species of plant from which they have come.

Other substances stored for reserve are in the nature of oils and fats, such as are found especially in seeds of cotton and flax. In fact, many seeds are the source of commercial oils. An important point to note in this connection is that the substances stored in their final form are not the same as those originally taken up by the plant. Very complicated chemical processes have taken place in the interval before storage could occur, and particularly in the direction of the solubility and the concentration of those materials. In this final form they cannot escape from the cells which contain them, by the process of osmosis; and this is evidently what has been aimed at. It therefore follows that before they can be utilised by the portions of the plant that require them, they must once more be changed into some soluble form of food which can be carried about in the plant by the usual food channels. This is probably

PROTEIDS WITHIN THE SEED

These cells from the endosperm of the castor-oil seed contain aleurone grains, which are proteid crystals combined with an inorganic body termed globoid. They are here magnified 200,000 times.

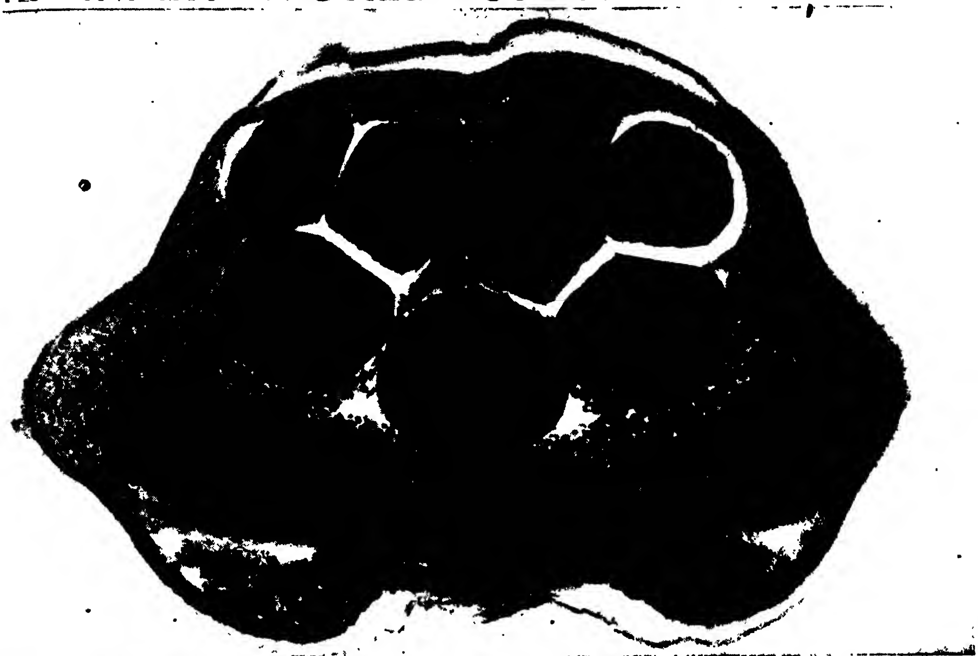
chiefly accomplished as the result of the action of ferments, or enzymes, produced by the protoplasm itself. These ferments are very remarkable substances, particularly in this respect—that they can digest, or transform, an almost unlimited amount of the storage food without themselves becoming used up in the process. One of them, which is termed diastase, has the power of transforming insoluble carbohydrates into sugars. This ferment acts upon starch, for example, in seeds which are germinating, and is especially prominent in the seeds of cereals. Another form of the same ferment is found in the leaves and shoots of plants; and by means of its action the starch which has been manufactured by the green parts of the plant during the daytime is actually transformed into sugar during the night. This same ferment is abundant in the regions of the "eyes" of potatoes. Here the starch, which is plentiful, is again transformed into sugar that can be readily carried to the area of growth.

Another ferment which digests these reserve materials in plants is named cytase and this is formed in the cotyledons of some seeds, such as peas. Its function appears to be slightly different from that of diastase inasmuch as it dissolves the cell-walls wherein the starch is contained, and thus allows diastase to act upon the starch itself.

In some of our common roots much of the organic food material constructed by the leaves in the first growing year is stored up in the root in the form of cane sugar. The carrot is an example of this. The beet is another. Here the reserve is available for use in the following season, but before it can be so used it must be acted upon by another ferment which splits up the cane sugar into more readily assimilated forms.

We have mentioned the presence of oil in considerable quantities in seeds such as flax, castor oil, cotton, etc. The ferment

THE INNER WORLD OF A BARLEY SEED



SECTION THROUGH THE RADICLE END OF A SEED OF BARLEY 12 HOURS AFTER GERMINATION

SECTION THROUGH THE PRIMARY ROOT OF BARLEY 12 HOURS AFTER GERMINATION

The upper photograph, magnified some 2500 times, shows the disposition of the cells in the primary or largest root and in the secondary roots. The lower photograph represents the primary root under still higher magnification. The nucleus can be seen in each cell.

that acts upon this form of reserve food, decomposing it, is termed lipase.

These examples will be sufficient to illustrate the process by which plants keep a store of food available either for their own seeds or for individual subsequent needs. There are other complicated processes, and still other ferments concerned, but the principle in all these cases is the same.

VARIOUS FORMS OF STARCH GRANULES

Many of the best examples of the storage of extra nourishment in plants are to be found in some of our most common biennials, such as the parsnip, the carrot, the beet, and the turnip, all of these being plants that do not produce seed in their first season's growth, but do so in the second. The immense amount of food stored in these plants gives rise to the *fleshy roots* which are their characteristic, and, at the same time, gives them their commercial value. Some other plants, with similar fleshy roots, exhibit the same phenomenon on a very much larger scale than those just mentioned. One plant grown in the United States (*Ipomœa jalapa*), a relative of the sweet potato, produces storage organs in the shape of roots, that may weigh as much as forty or fifty pounds. Sugar and starch are the main food thus stored. Beetroots contain sufficient sugar to produce a large part of the supply of that article of food for Europe. These biennial plants obviously spend the first year of their lives in accumulating this store of food, to be used later. The stem of the second year, which grows very quickly, depends upon this store for its nourishment; and if the root, so large to begin with, be examined at the end of the second year of growth, when the flowers and the seed have been produced, it will be found very much shrunken and withered, because the food stored up in it has been utilised.

STARCH GRAINS WITHIN THE CELLS OF THE POTATO TUBER AND ORCHID ROOT

The photograph on the left is magnified some 2000 times, and that on the right some 30,000 times.

Perennial plants, also, have similar storage organs, excellent examples of which are seen

in the common rhubarb and the sweet potato. A number of these plants die down completely above the surface of the ground on the approach of winter, but make most abundant growth at the first approach of spring, thanks to their fleshy roots and the food within them.

LONGITUDINAL SECTIONS THROUGH AN ONION AND A LILY, SHOWING THE BULB SCALES

But it is not only in roots, using that term in its proper sense, that this storage takes place, for we find many plants doing the same thing for the same purpose by means of their underground *stems*. These can be distinguished from roots by, amongst other things, the presence upon them of small scales, that are really in the nature of leaves. Perhaps the best example of an underground stem of this kind, developed for this purpose, is the common potato, which develops the short, thick, underground stem called the *tuber*. A careful examination of the whole of a potato plant will show at once that what we call the potatoes—in other words, the tubers—are not developed on the true roots at all, but are attached to branches of the stem that happen to lie underground. What are known as the "eyes" of the potato are rudimentary buds.

THE SCALY BULB OF A TIGER LILY

Other examples of underground stems are to be found in many bulbs, some of which have thick scales, like the lily. We have said that most of this storage is for the purpose of carrying these plants over the winter season. But it should be added that that remark applies to our own climatic conditions. In other parts of the world, where there is what is termed the dry season, as opposed to the rainy season, the storage of food is required to carry the plant over the dry season, and to enable it to grow more rapidly during the wet season.

Perhaps the most extraordinary case, from some points of view, of the phenomenon of food storage in plants is to be found in the sago palm. Here the surplus food is accumulated in the trunk; and in this plant as much as eight hundred pounds in weight of food material in the form of starch may be accumulated. The outer rind of the stem of the palm consists of hard dense wood, about two inches thick, and inside is an enormous mass of spongy pith which is extracted after the tree is cut down at the age of about fifteen years. This pith, after preparation, becomes the sago used in the household.

We see, therefore, that starch is a common form of food to be stored, not merely in seeds and in roots, as has been already mentioned, but also in the stem of plants,

TYPICAL MEMBERS OF THE CIVET TRIBE

THE BANDED MUNGOOSE, OR CUSIMANSE

THE WHITE-WHISKERED PALM CIVET

THE PARDINE GENET, WHICH IS KEPT AS A PET IN SOUTHERN EUROPE

THE SUMATRAN CIVET

THE MEERKAT, OR SURICATE

The photographs on these pages are by Lewis Medland, W. P. Dando, C. Grant Lane, T. A. Metcalfe, and others.

ANIMAL FRIENDS AND FOES

An Imminent Danger from the Upsetting by Man of the Natural Balance of Wild Life

ENORMOUS LOSS FROM PROLIFIC PESTS

A LAW, more honoured in the breach than the observance, it is to be feared, requires a railway or other company to substitute new houses for old when workmen's dwellings are demolished for some new enterprise. Some day, when man's relations with the animal world are intelligently controlled and directed, we may have a law insisting that if a natural safeguard against the over-multiplication of injurious forms of animal life be removed, another as effective shall be provided. The destruction of Nature's police will be recognised as an offence as serious as arson—or poaching! We sharply fine or imprison the yokel who takes hare, rabbit, pheasant, or partridge, but the man who cries out against the poacher is at liberty to slay weasel and stoat, owl and hawk anything that might conceivably snatch a nestling from the birds he preserves for the savage joy of shooting. The death of every one of the carnivorous animals and birds mentioned represents, in its effects, a serious loss to the country. The death of each means immunity from capture for so many rats, mice, and voles.

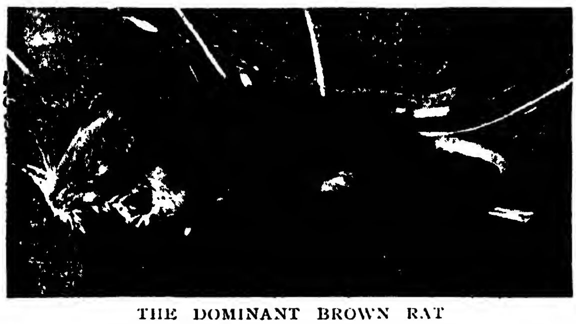
Of these, the rat alone costs the United Kingdom fifteen millions sterling a year. Field-mice, or voles, constitute recurrent plagues, and in the past have brought agriculturists to the brink of ruin, in Scotland, in Essex, Kent, Gloucestershire, and Hampshire. Water-voles, or water-rats, as we more commonly term them, ruin whole plantations of trees near their haunts, and sometimes work swift destruction on a country-side by tunnelling through the banks of canals, rivers, and dykes. The bank-voles rob trees of their bark, and ruin timber growths by climbing the trunk to a height of ten or more feet, and, by eating the lateral and terminal buds, produce dwarfed and distorted stems. Mice pillage harvest field, granary, and stack, besides consuming and spoiling huge quantities of food and goods in dwellings and other buildings. It is a law of Nature that the number of individuals of a species shall remain, through a course of years, practically stationary. We have seen, in previous chapters, notably in that dealing with the bulk of the rodents, by what ruthless processes the mean is preserved. But if man in his selfish folly removes the checks which Nature furnishes, then the balance must of necessity be upset. And, such checks having been removed, the balance of Nature *is* disturbed; the earth is plagued today with that remnant of the rodents for which consideration is reserved to the present chapter.

Carnivorous birds and animals alone cannot keep down this plague, but their slaughter deprives us of our most potent natural aid. These furred and feathered police are mainly nocturnal, and so are the animals upon which they prey. The average man does not see a rat a year, yet they are, with the mice and voles, the most numerous animals in the land, and unparallelled as workers of mischief. We have no means of estimating the number of rodents killed by a weasel, but we do know that, for every one it kills for food, it slays a dozen more to gratify that strange instinct for slaughter which makes it so redoubtable an ally against vermin The owl's good work may be estimated from superficial evidence: traces of hundreds of rate and mice mark the site of its nest. Now, every couple of rats that these birds or animals destroy might, if left to multiply, become the ancestors, in the course of twelve months, of eight hundred other rats. Their powers of increase are astounding. Rats can breed in every month of the year, and do produce from six to seven litters,

ranging from six to nineteen, with an average of ten or eleven. One female, kept under observation, produced seven litters in as many months. The young, though not attaining full development until eighteen months old, begin to breed before the end of the fourth month. And they live and multiply at the cost of human health and property. How far they are a menace to life, the most serious of all aspects, we must presently consider, keeping for the moment to the less formidable counts.


THE BLACK RAT, ALMOST EXTINCT IN BRITAIN

The mice and voles are appallingly prolific, and would command general attention as a menace to agricultural and commercial prosperity were not their case rendered relatively less serious by comparison with that against the rat. But two illustrations of a different type may be cited as throwing light upon the point. Take, first, a plague of field-mice and voles in the Forest of Dean and the New Forest. The rodents suddenly appeared in swarms in all parts of the forests, destroying so many young trees that only four or five trees to an acre survived. They killed these growths either by gnawing the bark or eating the roots, or both. Many inventions were devised for their extermination. One expert dug pits, into which the vermin fell helpless, and there ate each other. Polecats, hawks, kites, and owls were attracted to the scene, and consumed vast numbers. One owl which had never previously been seen in the neighbourhood made its appearance. In spite of all the assistance thus rendered, the digger of the pits drew payment for the slaughter, it is stated, of 100,000 of the animals before the plague was stayed.


THE DOMINANT BROWN RAT

So much for the abnormal. Now for a normal presentment. A letter in the *Times* described the threshing of seven stacks of corn, and, apart from those killed by dogs or otherwise destroyed, men slew and collected *six stones* of mice. A careful observer took the trouble to get the statistics. He found that it took about 315 mice to make up a stone weight. Thus, in these seven stacks of corn, over 2000 mice were killed by men, in addition to the number otherwise disposed of. And the corn wasted by the robbers in these few stacks represented twenty-four quarters, or, in money, nearly £40! Yet if an owl or one of our small carnivora had appeared in that farmyard, hunting for vermin, it is probable that a gunshot or a bludgeon would have put an end to the beneficent chase!

For many years the country has witnessed, without effective protest, the destruction of serviceable birds and carnivora, with vast increase of rodents as the result. The increase of rodents in country districts is followed by a corresponding increase in the towns. As weeds and insect pests spread across a continent, so do rodents, but at an infinitely quicker pace. While rats, a few years ago, were establishing a reign of terror in certain small towns and villages in Essex, London was daily and nightly witnessing pandemonium, rat-created, in main thoroughfares such as Fleet Street and the Strand. In the heart of newspaper-land the rats, disporting within the hoardings surrounding dismantled buildings, drew such crowds that the police had hourly to "move on" the sightseers. In the Strand, at one restaurant alone, the rats did damage amounting, it was stated, to £500. In close succession came a series of sensational incidents illustrative of the widespread range and destructiveness of these animals. Their operations led to the undermining of certain masonry and the bursting of three reservoirs in Connecticut. Their ravages at Turin necessitated the employment of tin cases for correspondence at the post-office. Their gnawing at the

insulated electric wires held up a London railway carrying twelve million people a year. Then there were reported over a dozen cases of human beings attacked by rats in the United Kingdom. A Lewisham infant was bitten to death; a Clonmel child had its nose bitten off; an Otley infant lost two of its fingers and sustained dangerous wounds on the head; a Campile (New Ross) baby was bitten almost to death; a similar incident occurred at Chiswick; while the naked breast of a mother nursing her child was attacked by a rat in Eton workhouse, where so voracious and fierce were the rodents that the pauper inmates went practically in fear of their lives. Only a few months ago, Canton, one of the largest districts of Cardiff, was completely terrorised by a rat invasion. But the game preservers continued to slaughter the natural enemies of the rat, and all was well in the coverts, if ill with the rest of the land.

Sir Lauder Brunton sounded a warning note. He showed how plague-infected rats arrive at our ports and transmit their disease to others, and how that plague is communicable to man. The plague, limited for a time, would become virulent, and, spreading along the railway lines, might penetrate to every part of the country. No notice was taken of the warning, but one part of the prophecy seemed strangely realised soon afterwards. A traveller by a night train from Peterborough to Grimsby complained that while he rested in his carriage an animal had run over his face. The officials did not take notice of the story until similar complaints were later forthcoming. Then an investigation was made, and it was found that the train was infested with rats. The vermin were travelling by rail, as Sir Lauder Brunton had suggested that they might. More warnings were uttered, only to be disregarded. There was, first, the question of the destruction of property; danger to life seemed a contingency too remote to appeal to the public imagination. On the first score, however, ample evidence was collected, and typical examples given were such as the following:

Bales of silk arrive in London riddled by rats and useless.

A cargo of frozen beef arrives gnawed to the bone.

Ten per cent. of fruit coming into port irreparably damaged by rats.

Incalculable damage to foodstuffs and other goods wrought by rats at the London docks.

THE FISH-RATS OF AUSTRALIA

Later, the hygienic aspect was attacked, and the results of modern bacterio logical research were given to the world. It was shown that the rat is "a veritable nursery of all the noxious disease germs which endanger the health of man." Rooting into all manner of festering garbage, the rat absorbs and becomes the host of the most virulent forms of microbic growth. Not only plague, and, in Germany, trichinosis, but horse-influenza is directly propagated by the rat; and it is more than suspected, the warning continued, that swine fever, rinderpest, and certain other forms of disease are spread abroad by, if not actually originating in, the body of the rat.

Cultures of the germs taken from the moist nose of a recently killed rat (said the *Times*) have revealed the presence of almost every known disease germ—even the microbe which has been proved to be the cause of tetanus (lockjaw) is usually there

discovered; and the spread of influenza among horses is now traced to the agency of rats. By getting into the corn-bins and nosing amongst the grain, they leave the germs behind for the subsequent introduction into the body of the horse.

The end of the appeal to reason was the formation of a society devoted to the extermination of rats. Three years passed, and rats still held the field against such opposition as they were called upon to face; and then the blow which Sir Lauder Brunton had predicted actually fell, though not with such violence as he had feared—lucky chance, not systematic safeguarding, bringing to light the fact that the dreaded plague, king of terrors, was raging in Suffolk, within less than two hours' railway ride of London.

THE KANGAROO RAT

There can be no doubt that ten human lives were sacrificed to the plague, but it was not until the seventh fatality occurred that suspicion was aroused. Then, bacterial cultures having been made from the blood of one of the victims, the plague bacillus was at once detected. Pneumonic plague, the most alarming form of the malady, had returned to England after centuries of absence; and though it attacked fewer than a score of people, of whom only ten died, yet the plague was found to be widespread among rats, rabbits, hares, and other animals throughout a considerable area in East Anglia. It was remembered, too late to save life, that a great number of dead rats had been seen in the neighbourhood, and that many of these had been handled. The origin of the plague among human beings then became clear. Of a large number of rats examined, 5 per cent. were found to be plague-infected. During the outbreak of plague in Sydney the percentage of rats similarly affected was never higher than ·37 per cent; while of the thousands of these animals caught and examined in Bombay, when the plague there was at its height, the average was rarely higher than 6 per cent. Thus, without the least suspicion, we had in Suffolk all the possibilities of an outbreak of plague such as ravaged the land centuries ago.

THE GAMBIAN POUCHED RAT

It became time to glance round the world to see what havoc rats elsewhere were working. Plague, originating in Hong Kong in 1894, had reached Bombay two years later and up to the end of 1910 had carried off at least seven million British subjects, a million having died in the Punjab alone in the course of seven years. It had reached Japan and Russia, and afterwards there came the terrible outbreak in Manchuria. In the latter case the marmot was blamed, but there was no doubt as to the rat being the origin elsewhere. Japan carried out a rat campaign, and in Tokyo four and a half millions of the rodents were destroyed in three years. The Japanese soldiers fighting during the winter against Russia were provided with fine warm protectors for nose and ears; and these protectors proved to be made of the skins of the rats for which the Japanese Government had been paying about a tenth of a farthing each! But, in spite of this great slaughter, it was estimated that the rat population of Tokyo was greater than ever! The survivors, having the normal food supply for division among lesser numbers, bred with greater freedom than ever. Both Japan and India abandoned the attempt to exterminate the rat as hopeless. Yet so long as there are a few rats in the world there is always the likelihood of an outbreak of plague.

The infected rat is bitten by a flea, which acts as host for the plague bacillus. That flea infects whatever living victim it may bite. From one rat and its fleas, many rats may become infected, and among the many one rat will pass on its parasite to a human being. The process is the same in India and in England, though the result may differ. The rat-flea caused an outbreak of bubonic plague in Glasgow a few years ago, where in the course of a single year 120 rats were found to be infected with *bacillus pestis*. But in England the plague

was pneumonic instead of bubonic. In the latter form the ailment manifests itself as a fatal disease of certain glands; in pneumonic plague it is the lungs which are attacked. The English is really the worse form, for the breath of a patient may cause death to every person near; the bubonic form is not infectious; in each case it must be preceded by the bite of an infected rat-flea.

The voice of science has gone forth against the rat. "If we are to stamp out plague we must first stamp out the rat." Both the black rat and the brown rat are equally susceptible to the disease. It was the black rat which, arriving in Great Britain in the early Middle Ages, brought the plague with it. The black rat has never been exterminated, although it exists in Great Britain in infinitely smaller numbers than its brown-grey cousin, the more powerful and savage beast that has driven it hence by direct attack and by process of starving out. But although the black rat was so scarce, or believed to be, in Frank Buckland's time, that he was at the pains to present the Natural History Museum with a better example than it then possessed, Sir Ray Lankester obtained specimens from a London warehouse as recently as two years ago, when the species was believed to have been long extinct. In other places, notably certain parts of Yorkshire, the black rat is still common; and as it disseminates plague, and was, moreover, one of the offenders mentioned in the catalogue of rat attacks upon human beings already cited, the black rat, too, must go—if we can make it.


THE HAIRY BAMBOO RAT


THE CANE-RAT

Poor countries such as Denmark and Portugal have conducted national crusades against these loathsome vermin; Hamburg has been driven to provide what is called a "rat-killer battleship" for the protection of her port against plague-infected rats carried by ships from other harbours. Concerted action will have to be taken in Great Britain. A product of the laboratory, a virus whose lethal properties are directed peculiarly against rats, is doing excellent work, but it is absurdly dear. Possibly it would not be a commercial possibility at a smaller figure, but the cottager whose little dwelling teems with hungry rats cannot afford to buy virus at half-a-crown a small tin, when several such tins may be necessary. The future of viruses may possibly lie with the Government, either by direct production or subsidy. It is useless for the wealthy man to clear his premises while the poor man still harbours droves of rodents.

Meanwhile it is imperative that not a bird or animal which can help to keep the rat in check should be killed. Owls should be rigorously protected by law, and weasels, and even stoats, be vouchsafed at least a close season. One of these rapacious little animals may occasionally take a hare, a pheasant, or a partridge, and even break and enter the domestic-poultry run. What is the cash value of such prey? What, on the other hand, is the cash value of the crops which, by killing rats, it saves to the farmer? Above all, what is the cash value to the nation of the human lives safeguarded from plague by these enemies of the rat which slay vast numbers of death-disseminating vermin?

There is one rodent that indirectly contributes to the food harvests of the world. Manitoba grows the finest grain, but has no earthworms to fertilise its soil. From Manitoba, and indeed throughout all that part of North America lying to the south of the Saskatchewan and west of the Mississippi, pocket-gophers are the great soil-makers. The deep, rich layer of soil from which the golden grain springs is the creation of these little rodents, who have mixed up the deep deposit of decayed vegetation with the underlying loam. By their burrowing and tunnelling they have unconsciously prepared

for man some of the finest, most fertile soil in the world. But the rest of their order levy heavy toll for this one benefit.

The rats and mice are an extraordinarily numerous family. Excluding the dormouse and dormouse-like forms, and the jumping mice, which are relegated to two different families, there are between thirty and forty genera of these animals. These, however, include rodents not popularly regarded as allied to rats and mice—such as the hamsters and lemmings and gerbils. The classification of this family must constitute a perplexing problem to the newcomer into the realm of natural history; for while the dormice are referred to one family, and the jumping mice to a second, which includes the true jerboas, the harvest mice are relegated to the genus comprising the true rats and mice, which is the thirty-first genus of the mouse tribe, while the tree-mice and the climbing mice, though included in the same family group with the latter, are far removed from genus thirty-one.

We have three known genera of dormice—the common, the squirrel-tailed, and the garden dormouse. The first, well known in the British Isles and throughout Europe, is arboreal and squirrel-like in habits. The second is unknown in Great Britain, but is widely distributed in other parts of Europe, though absent from Scandinavia. The true dormouse has a more limited European range, but is found in Siberia, and has an ally in the brightly coloured little Persian species known as the painted dormouse. The garden dormouse, which swarms in Southern Europe, where it does great damage to fruit, is interesting as one of the few animals known to be immune to snake-bite. Not only is this mouse immune, but its blood, after an infusion of snake venom, immunises other animals submitted to inoculation. Closely allied to the dormice are the spiny mice of India and China, strange little animals, haunting large trees or excavating small hollows. They have developed a defensive armour similar to that of the porcupine, and are a sort of stickleback among rodents.


A FAT DORMOUSE

The jumping mice, with their elongated hind legs, curiously resemble the jerboa, but they exceed even that animal in activity. A jumping mouse possesses, says an observer, a momentary agility second to no other rodent, and a muscular strength of enormous power for so small a creature. Its leaps measure eight to ten feet in length, though they rapidly diminish to half the former distance. It can elude the weasel and the snake, and by a swift manœuvre escape the attention of hawk or owl. It is an enemy to trees, eating young shoots and bark.

Australia possesses two native rodents, of which one is a genus of water-rat. As it is essentially an aquatic animal, it has so far not proved obnoxious. The gerbils follow almost immediately in the classification, but are far different in appearance, though in the same family. They are restricted to the Old World. Jerboa-like, they jump twelve to fifteen feet at a bound, and are exceedingly difficult to catch. They are a pest to cultivated crops wherever found in the vicinity of human dwellings. While the Old World possesses white-tailed rats, which the New World lacks, America has white-footed mice, unknown elsewhere. These are expert tree-climbers, omnivorous in diet, and a plague in the ricefields. They must not be confused with the ricefield mice proper, for these are a distinct genus, of which the typical species is known as *oryzomys palustris*.

As the otter and other carnivora have taken to life in or about the water, so have certain rats other than the so-called true water-rats. Conspicuous among these are the specialised fish-rats of South America, which make their homes in the mountain streams of Peru and Ecuador, where small fish constitute their diet. One species has already lost its external ear, while these conches are gradually disappearing from the ears of *Anotomys leander*, a species found in the highest streams of Ecuador—another example of evolution before our eyes. A further adaptation to circumstances, as we must deem it, is found in the habits of the Florida wood-rat, the young of which cling.

opossum-like, to the back and sides of the doe as the latter runs about in search of food. A rat we ought to know more about is the crested rat of Abyssinia, Somaliland, and Eastern Africa. This strange creature has a crest of hairs, some of them as much as 3½ inches in length, which can be erected at will. In the hind foot the small front toe is opposable to the others, and serves as a thumb.

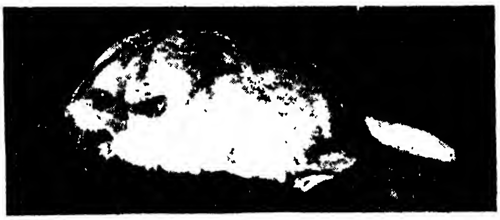
The British water-rat and half a score of field-mice, but not the long-tailed field-mouse, are grouped to form one genus. The first-named is really our indigenous rat, the black and the brown being, as already noted, alien introductions of later date. The water-rat or water-vole is a purely vegetable feeder, making long tunnels in river banks, ruining osier-beds, destroying the bark of trees, and working havoc, when pressed for food, among root crops. The short-tailed field-mice cause great destruction of seeds, roots, and bulbs, and, in winter, bark of trees. They produce three or four litters of from four to six or more each summer.

Our classification leads us back to the true rats and mice; and perhaps it is unnecessary to add more, except that while the house-mouse is nearly as prolific as the rat, and practically omnivorous, there is no record of its ever having attacked a human being or any living animal. Long-tailed field-mice swarm into buildings and dwellings during winter. The two species may be distinguished without difficulty. The house-mouse is nearly uniformly brown and only slightly lighter below, while the field specimen has excessively large ears, a tail equalling the length of the head and body, while the fur is reddish-grey above and whitish beneath, with a brown spot on the chest. Both species are among the enemies of home and farmstead, unredeemed by a single act of service to mankind. The harvest mouse shares with the pigmy shrew the distinction of being the smallest mammal. Six harvest mice go to the ounce. But each female harvest mouse, if left at liberty, gives birth to three or four litters of mice per year, a total of from eighteen to thirty-four, and they all live almost exclusively upon the farmer's crops. During the winter they sleep, if out in the open, in burrows in which they may store food, or pass the cold weather hibernating. When the crop is springing up they construct their nests, with marvellous neatness and skill, upon the stalks of the corn, and in these their young are born. When the corn is cut, thousands of harvest mice are carried out with the sheaves, to the stacks and granaries, and there pass the winter in activity, sharing with other mice and rats in the plunder of the farmer's store.

The British house-mouse

Brandt's mouse of Bechuanaland

The spiny mouse of Egypt



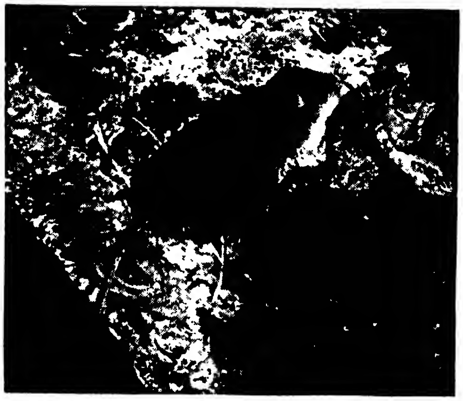
The fat-tailed mouse

FOUR DIVERGENT TYPES OF THE NUMEROUS MOUSE FAMILY

There are several other mice and rats and rat-like animals—bandicoot rats of Southern Asia, bush-rats of India and Africa, giant rats of the Philippines—one, the whip-tailed, having a body-length of 18 inches and a tail 15 inches in length, and a second giant rat of the same latitude renowned as a tree-climber. Then we have the mole-rats, the bamboo-rats, sand-rats—almost hairless, these latter—the kangaroo rats, so called, not from any relation to the marsupials, but from the shape and proportions of the hind legs and their kangaroo-like progression. Another of the rat-like group, the octodont tribe, is said to contain twenty-seven genera,

distributed over Africa, the West Indies, and South and Central America. Among them we have the curious African gundis and cane-rats, the Chilian and Peruvian degu, and the South American tucuto, an animal which, like the mole and one or two other animals, is slowly sacrificing sight to touch.

All these animals are, without qualification, enemies to man in so far as they destroy his food, his flowers, his potential timber. Many of them are difficult of access. Given sufficient food, they multiply with extraordinary rapidity. And it is a simple fact that at present man depends rather upon their natural enemies than upon his own efforts, not, indeed, for their extermination, for that is not an immediate possibility even were it desirable, but for maintaining some sort of check upon their increase.


THE FIELD-VOLE ON A HEDGE-BANK

When rats were terrorising the inmates of Eton workhouse the master of the latter reported to the guardians that among many suggestions a bishop's wife had advised him to get a mungoose. The guardians, without audibly guessing whether a mungoose might be a virus, a trap, or a spring-gun, left the matter to the master. The latter reported at the next meeting that he had ascertained that "a mungoose is a savage animal." All sorts of fierce apparitions may have leapt to the official mind at the saying, but, although the mungoose is not exactly a drawing-room pet, it is certainly not more to be feared than the domestic ferret, while it is more intelligent and a less noisome beast. Although it may occasionally help itself to poultry, the mungoose is decidedly an ally of man, in that it wages war upon his enemies. It is a member of a diversified assemblage of animals, which, including the true civets or civet-cats, the genets, ichneumons (or mungooses), foussa, linsang, palm civets, etc., is grouped as the civet tribe. External outline suggests kinship with the weasels; but whereas the latter are from the same stock as the bears and raccoons, the civets are linked, through the foussa, with the cat tribe. The foussa is peculiar to Madagascar, and, being a strictly nocturnal, unamiable creature, has not been as closely studied as it ought to be. There is some reason to believe that the foussa is the descendant of small, cat-like animals whose fossil remains are found in Oligocene Tertiary deposits in France—an interesting theory, in view of the fact that the existing lemurs of Madagascar are thought possibly to be descended from extinct French lemurs.


THE WATER-VOLE, OR WATER-RAT

The civets are nearly all exclusively carnivorous, untiring hunters, and, as to most species, expert tree-climbers, thanks to their retractile or semi-retractile claws. They are all nocturnal, hunting for food when the "small game" on which they prey are also abroad. But, as all the world knows, the civet has an economic value in respect of the peculiar scented secretion which collects in the perineal glands of the animal. This secretion, which enters the scent pouches in the form of a thick fluid, hardens upon reaching the air, and retains a penetrating odour which makes it highly esteemed in the East as a perfume. Formerly the secretion was held to possess valuable medicinal properties, as, indeed, most of the unlikely animal products were. It was of a generous "cardiac" containing several such substances, prescribed by his sixteen physicians, that Charles II. died. In order that the civet perfume may be obtained, the animal is kept in captivity, and, at

time, placed in a long, narrow .hich prevents it from turning to .eeth or claws. The substance is then painlessly extracted, by means of a bone instrument, from the pouch in which it is contained. The perfume is obtained from the African civet, the Indian civet (of Bengal, China, and the Malayan region), from another species of distribution practically similar to that of the last named, and from the rasse, the smallest member of the group, which is found in India, Ceylon, Java, China, and elsewhere in Oriental lands.

The Unobjectionable Genet, Already Used in Southern Europe as a Houseguard against Mice

The genets, which lack the scent-secreting glands of the true civets, are confined to Africa and parts of Europe and South-Western Asia. Although very little different in temperament from the rest of their family, genets are easily tamed, where man has taken the trouble to try the experiment. They are commonly kept in Southern Europe as houseguards against rats and mice. Passing the linsangs, active, carnivorous little animals which eke out their diet with insect additions, we reach the palm-civets, of which there are several species, tree-haunting animals which derive their name from their habit of drinking the palm-juice collected by natives in vessels hung upon the trunks of palm-trees. A near ally is the binturong, in the young of which the tail is completely prehensile, and even in the heavier adult never quite loses its gripping power. The range of the binturong is purely Oriental. The civet family has a semi-aquatic representative in the water-civet, which, quite as much at home in river and stream as the otter, is yet a first-rate tree-climber and hunter upon land.

The Mungoose, a Fine and Fierce Hunter, and also an Affectionate Pet

The mungooses share with the genets the distinction of sole representation of the civet-like group in Europe. The European type (genus *Herpestes*) is also spread over Africa, India, and the Malayan countries. In this genus are included all the true mungooses, some dozen or more species. The remainder are grouped in nine distinct genera, exclusive of the meerkats. Of this number, Madagascar claims four genera, and one, the *Eupleres goudoti*, appears from its teeth to be dependent solely upon an insectivorous diet. It is with the common mungoose, however, that we are more concerned. "The savage animal" suggested by the bishop's wife is a fierce little creature when its liberty is suddenly threatened, but few animals are more easily tamed, and few show greater affection and gentleness towards human beings. The mungoose is not only the great enemy of snakes; it is incomparably the finest hunter of rats and mice, insects, and the noisome lizards which infest Oriental dwellings. A mungoose will rid ship or house of rats and other vermin, but it will poach poultry if permitted to do so, just as a well-fed cat may occasionally do. The Egyptian mungoose is an enthusiastic devourer of crocodile eggs, and just as assiduous a hunter of snakes and other undesirable forms of life. There can be no doubt that the mungoose is one of the most potent animal allies that man has in the East against the loathsome rat, to say nothing of its service against snakes. It was long a debated point as to whether the marvellous activity of the little carnivore protected it from the deadly poison fangs of the snake, but recent experiment has shown that the mungoose is practically immune to serpent venom.

The Drawback of Giving any Predatory Animal Free Breeding Room

Of course, it is not suggested that mungooses live simply to oblige us by killing our enemies; mungooses, excellent as allies, themselves become a pest by over-multiplication, as an experiment in Jamaica proved. When rats overran the island and threatened the entire ruin of the sugar-planting industry of the island, mungooses were introduced as a last hope. They exterminated the rats, but, their own food supply running low with the shortage of rats, they played havoc with other forms of life, both animal and bird, and the outcome was a succession of insect pests as destructive as the rats. Then the mungooses had in turn to be removed.

Jamaica's experiment was an object-lesson. Rats, permitted to multiply without check, brought the island to the verge of ruin; and the remedy, artificially applied, eventually proved as costly as the ill. Upon a wider and therefore less obvious scale a similar thing is in progress throughout Great Britain. We have almost obliterated all the free natural enemies of rats and mice, and we are paying £15,000,000 a year as the cost, in addition to occasional toll in human life. And, in spite of all our lessons, we are continuing along the same path, as every man who permits the destruction of carnivorous bird or animal in these islands is witness.

THE EMPIRE OF THE MIND—VISIONS THAT CONTROLLED THE DESTINY OF NATIONS

THE VISION OF JOAN OF ARC, WHICH LED TO THE LOSS OF THE ENGLISH DOMINIONS IN FRANCE, PICTURED BY M. ADRIEN BONN

MIND THE ESSENCE OF MAN

The Mind, Something Vastly More Than Consciousness, to be Studied in Lowly Ways, but Linked with the Divine

AN INTRODUCTION TO PSYCHOLOGY

With certain conspicuous omissions, such as the eye, we have now discussed the body of man, "in whom there is nothing great but mind." We have steadily climbed upwards until we reached the grey bark, or cortex, of his brain, which is his characteristic organ, and which we have sliced and stained in the vain search for his soul. The truth is that "the things which are seen are temporal," and the essential part of man has not yet engaged our attention. To that essential part our next chapters must be devoted, though we shall by no means take leave of his body, and shall discuss the structure of eye and ear now, of deliberate intent, in preference to discussing it previously.

True, we have already made many references to mental aspects of man, for that was inevitable when we were studying his nervous system, which is bodily and material, and can be pulled apart upon the dissecting-table, but yet can only intelligently be dissected with reference to its functions, which are more and other than physical. Hence, while for convenience we divide our discussion of man into two great parts—the first, which was concluded in the last chapter, dealing with the physical, and the second with the psychical, aspects of this double being—yet it was observed that, in discussing his body, we often had to mention his mind, and it will be observed that in discussing his mind we have to make repeated reference to his body. These are not unfortunate necessities, nor due to confusion in our treatment of our subject. They are in the nature of the case; and the modern epoch in our knowledge of man is indeed constituted by our new ideas as to the true relation between his mind and his body.

In the curriculum of medical study in any university or medical school in this country, the student early encounters two great subjects which are really one, and are called anatomy and physiology. They deal respectively with the structure and the working of the body. But though this student will some day have to deal with insane patients, and indeed will be studying morbid psychology in a few years, there is no course on normal psychology in the statutory or required curriculum of any medical school in this country. And we may well ask how this obviously insane state of affairs, which constantly leads to such disastrous consequences, comes to be.

The answer is found when we cross the quadrangle, say, from the faculties of medicine and science, where anatomy and physiology are taught, to the faculties of divinity and arts. There, to our surprise, we find classrooms devoted to such subjects as metaphysics, psychology, and logic. Thus on one side students are studying the normal body and the abnormal mind; while on the other side a different group of students, destined for different professions, are studying the normal mind, but not the body at all, nor the abnormal mind! The simple truth is that our ideas on these matters are still chiefly derived from the ignorance and superstition of the past, when the doctors of divinity despised the body, and would not be seen speaking to the barber-surgeon or the apothecary; and these retorted by regarding the divines and scholars as deluded fools, who, nevertheless, had to submit to knives and pills at last. The student of the soul would be grossly insulted at the suggestion that perhaps if he had a little understanding of the functions and nervous connections of the stomach he might have the key to certain states of the soul, and the student of the stomach simply denied the existence of the soul at all.

Thus arose the sharp distinction between physiology, the study of the body, and

psychology, the study of the mind, which is best illustrated by the truly amazing fact that in no normal curriculum in this country are the two to be found, though many will be met which contain one or the other. But we have already learnt enough of man to see that this most unnatural divorce between his two aspects cannot be maintained. We simply cannot discuss either of them usefully and wisely without reference to the other; and students of this section may easily imagine the kind of contemptuous nonsense which must be talked, on either side of our quadrangle, of those who are engaged on the other side. We, however, in the twentieth century, cannot afford to share in these follies, nor have we any excuse, for we are not pledged to any particular faculty of any university —faculties which were divided up centuries ago, before the dawn of the modern age; and we can freely follow the few great men whom those faculties have produced, or who have survived their embraces, and who have succeeded in breaking down these artificial obstructions between the sciences of body and of mind.

Students of Both Mind and Body who are Teaching Physiological Psychology

The great students of the mind whom we shall follow are no doubt still spoken of very dubiously in classrooms of metaphysics and in some theological halls, but they have been steadily coming into their own during the last decade; and such authors as Wilhelm Wundt, William James, Henri Bergson, and William McDougall, who are students both of mind and body, and who have taught us to think not only of physiology and psychology, but also of *physiological psychology*, are already being quoted and studied by many who looked with something like hatred upon their spiritual progenitors, such as Herbert Spencer. And, on the other hand, the physiologists of twenty years ago, who thought they could explain man without mentioning his mind, already begin to read very foolishly to our eyes; and even such a great man and honest thinker as Huxley, when he talks of consciousness as an "epi-phenomenon," a sort of accidental by-product of the working of the brain, raises doubts in our minds today as to whether he had ever begun to think seriously about the subject at all.

The times have therefore changed. The philosophers and divines and psychologists on the one hand, and the doctors and physiologists on the other hand, are coming together; they are finding that they have a great deal to learn from each other, and they are constructing between them the foundations for a new and true science of the whole man, which shall sneer neither at the findings of the microscope nor the intuitions of science, but shall realise that all facts are part of Truth, and that in man, as nowhere else, the worlds of mind and matter meet and fuse, and become one visibly and palpably, as indeed they are one everywhere, in the eyes of philosophy.

The Science that Reconciles the Claims of both Matter and Spirit

In our account of man today, therefore, we naturally proceed from his body to his mind, and, above all, from the cortex of his cerebrum to his mind. We pass from physiology to psychology, and yet we do not leave physiology. We study the mind, but we still study the body. This, of course, is what is meant by and involved in the new science of physiological psychology, which rightly claims for itself today a place second to none among the sciences. Metaphysicians and psychologists in the past—and those who, though present in the flesh, belong to the past today—would sneer at this new science as materialism, because of its continued references to the body; and the physiologists of twenty years ago had a short enough way with any psychology, since to them the mind was, as we have seen, a physiological accident.

Let not the reader suppose that we are insisting unduly upon this tremendous change in the dominant thought of the recent past and today. It cannot be too much insisted upon.

Huxley's By-Product of the Brain the Essence of Man

The comparison is epitomised in the writings of such great and representative authors as Huxley and Tyndall on the one hand, and Bergson on the other. To Huxley, consciousness was a by-product of the working of the physico-chemical machine called the brain, and he successfully imposed that view upon the majority of men of science in his day. To Bergson, all life whatsoever is at bottom psychical, a manifestation and expression of mind; and the mind of man is simply the supreme instance of this truth, illustrated in parallel with the supreme organic or material achievement of life which we call the body, and especially the cerebrum of man. In a word, that part of man which, for the scientific aberration of a few decades ago, was an accident, is now regarded, by the greatest

psychologist and philosopher of our day, as the essence of man. This is doubtless the most widely held view of all, as the study of man's religions proves, but only in our own time has it begun to rank as the view which is forced upon us in the dissecting-room, through the microscope, and in the laboratory of the psychologist.

That last phrase expresses, as briefly as may be, the epoch-making and revolutionary advance which has been made in the past generation. The first psychological laboratory in the world was founded by the German pioneer Wilhelm Wundt, who is still living. The mere term marks an epoch.

How Spencer Saw that Evolution Involved the Evolution of the Mind of Man

Hitherto the typical psychologist has been a man like Kant, who thought about his own mind, and wrote down the conclusions to which he came; or like Spinoza, the immortal lens-polisher of Amsterdam. The very idea that a student of the mind could want a laboratory was inconceivable; one would as soon have expected a poet or a historian to demand a laboratory. Of course—as we now say, when we know—the discovery of evolution was bound to change all that, though the astonishing fact is that only Herbert Spencer, of the evolutionist pioneers, saw what now seems so plain to us. He alone saw that the doctrine of universal evolution, of which he was the apostle, must apply to mind as well as to everything else; and it is to his honour, therefore, that he set to work to build a true psychology of adult modern man upon such knowledge as could be obtained in his time regarding the minds of savages and children and the lower animals. But it was only after many years that Spencer began to see how mind comes into the process of evolution; and his famous definition of evolution is framed entirely in material terms of matter and motion. Nor had Spencer a laboratory.

The Modern Laboratory Study of the Joint Evolution of Mind and Body

For us, today, the evolution of life and the evolution of mind are parallel processes, for the best of all reasons, which is that the series of organic events which we call life have mind underneath them all. The mind-changes and the body-changes go on together, and this is true alike whether we survey the history of life, whether we observe the development of a baby into an adult man, and his development into a dotard, or whether we study mind and brain in their diseases. No wonder, then, that we have a "physiological psychology," a science which studies mind and body together, which means, in practice, studying mind through body, for mind is ever invisible. Hence the need for a laboratory. In it we must have and employ almost every kind of apparatus that is found in an ordinary physiological laboratory, but it will be the invisible mind that we are studying all the time through the visible body. We shall even perform a great many ordinary physiological experiments, where the older physiologists saw nothing but the machinery of nervous action, and we shall perceive that mind is here to be observed also. Today, in Germany, France, and the United States of America, many such psychological laboratories are to be found, nor can anyone place limits to the future achievements of the young science which is growing within them. Steadily it provides support for the doctrine which is known by the name of *psycho-neural parallelism*, a phrase which expresses the relation between mind-changes and body- or nerve-changes, which we have been trying to describe.

Knowledge of Mind, as of Body, Best Reached by Study of Details

And now we are ready for the first step, which may very well strike the young and eager psychologist with unpleasant surprise. He has set out to study this stupendous thing—incomparably the highest thing of which we have immediate knowledge—the mind of man; and it had not occurred to him that he would be troubled with the minute details of such a matter as the response of a moth to a light, or the jerking of a tapped knee-joint But if the young student's surprise persists, it will be clear that he has not grasped at all the real meaning of the new psychology. Let him learn from the body. The anatomist and physiologist wish to understand the working of man's body; and they begin by trying to understand the meaning of the fact that this body is made up of billions of tiny units called cells, which can only be distinguished under the microscope. Only by this route will they ever be able to understand how the body breathes, feeds, or moves. And the other sciences confirm this notion, for they show that the body of any man is developed from a single cell, and the human race is descended from living creatures whose bodies consisted of only single cells. There is thus no room for doubt that, if we are to understand the body of Hercules or Apollo, we must begin with the all but invisible cell; and, in fact, our modern understanding of the body of man dates from the discovery of

the cell-structure of plants; and just in proportion as we learn about the life of the cell do we learn about the physiology of the body.

Just so is it with the human mind. It is as easy to write *mind* as to write *body;* and we may think of each as simple and single. But directly we begin to look at the body, we see that, though in one true sense it is simple and single, in all other senses it is infinitely, immeasurably complicated; and only when we get into its intimate complexities shall we have the slightest chance of understanding its wonderful unity.

The Mind, Like the Body, Only to be Studied in Elemental Detail

And the mind, which is the invisible mate of the body, is similar. It is simple and single, in a true and all-important sense, but it is also infinitely, immeasurably complicated; and never shall we understand the mind, and the unity which it displays, until we have searched its details, just as the microscopist seeks to understand how the body, as a single simple whole, resists disease, by staining and comparing the nuclei of all the different kinds of white cells that inhabit the blood, and even then he is only at the beginning of his subject.

Therefore we do not begin by a study of, say, the conscious mind of Shakespeare as he wrote "Hamlet," or of Newton as he framed the laws of gravitation. We must take the mind little by little, as we have been compelled to take the body. We found ourselves compelled to dissect the body and decompose it, so to say, into its various elements. So must we do with the mind.

The first great fact which is forced upon us is that there is more in mind than meets the eye of consciousness, just as there is more in the body than meets the gaze of an observer. This is, on the whole, the greatest discovery of modern psychology, and we must be clear about it.

Consciousness or Awareness Only the Surface Flow of the Mind

In the textbooks of a generation or more ago we find psychology described as the science of consciousness; and the assumption was that a man's consciousness and his mind were one and the same thing. From this it followed that, if one looked into one's own consciousness, one would see the whole of one's mind.

But the tremendous discovery of our own times is that, when a man looks into his own consciousness, he does not and cannot see the *whole* of his mind. Consciousness, or awareness, can only be conscious or aware of what *is* conscious and aware in itself. We feel what *we* feel. But our predecessors went on to assume that there was no more to discover. Mind, to them, was simply and solely that which knows or is aware of itself, and of things outside it. We can imagine the difficulties in which they found themselves when they tried to explain where a man's mind is when he is unconscious, as every man must be for something like a third of his whole life.

But if we think of the mind as a deep river, rushing through a gorge, a river perhaps infinitely deep, then we may picture the consciousness of a man as being just the rippled, flowing *surface* of that river; indeed, psychologists often find it convenient to speak of "the stream of consciousness." Now, if we were looking at that river, in sunlight, we should just see its rippling, shining surface. We might try to describe it and paint it, as if that wonderful surface were everything. Yet, though the eye can see no more, a plummet would drop through that surface, and might never touch bottom.

The Abyss of Human Consciousness Not to be Plumbed by Introspection Only

Modern psychology has used that plummet. By slow, exact, critical processes, by the study of frogs, and even plants, as well as men, it has come to see that consciousness is only, so to say, the lit and visible *surface* of the mind, which has immeasurable depths beneath. Wise men have perceived this truth in all the ages, not least those men of strong and ardent nature who sought to understand and to control themselves, and thus began to learn how deep they really were. Perhaps the most famous illustration of this is to be found in a phrase of St. Augustine, a noble and profound thinker who had led a thoughtless and even wicked life in his youth, and then underwent what we nowadays often call "conversion." He speaks somewhere of what he calls the "abyssus humanæ conscientiæ"—the abyss of human consciousness. By that deeper and subtler introspection which comes from the heart and from the soul's ideals, no less than from the head, he knew how deep, how little explored, and how important are the depths of mind upon which the surface-stream of our conscious lives is supported.

Modern methods of research, of many kinds, have proved the truth of Augustine's phrase. The laboratory has furnished clear evidence of mental processes, which we can positively infer from their results, though the

conscious mind of their subject has no record nor knowledge of them. The study of dreams, after a long period during which science despised them as the will-o'-the-wisps of superstition and credulity, has abundantly revealed the existence of these depths, mental, active, potent, but unperceived by the ordinary consciousness, within the minds of all of us. And the late Mr. F. W. H. Myers, in his great book on "Human Personality and Its Survival of Bodily Death," and especially in his study therein of the processes of genius, has shown what stupendous forces of mind may be at work, far below the level of the surface-stream of consciousness, and may sometimes produce mighty uprushes, eruptions, upheavals, bursting up into the light of consciousness from depths unimagined even by their possessor, who does his creative deed, in thought, or music, or poetry, or *conduct*, and can only say that he feels inspired. If we think of the river of mind as a part of the infinite ocean of Mind, which makes and sustains and moves and is the Universe, this old idea of the inspiration of the poet and the prophet and the hero, the spirit that whispered his thoughts to Socrates, or that nerved the child's arm of Joan of Arc, is seen to be not so wild or foolish as some would have us to suppose.

This, of course, is not the place in which to pursue that great subject further; yet the image of the river, which we have ventured to employ, and to which we shall return, may here be insisted upon. For rivers exist, or may be imagined, which communicate at least with immeasurable masses of water under their floors, rivers up through whose beds there may sometimes surge floods from the "Great Deep." Such floods could cause a river to overwhelm its banks and burst into fresh channels, or could urge great currents that sweep forward whatever may be borne upon them—a book, an enterprise, a research, a heroism of some ardent moment, or of lifelong patience. Then is it that, in Wordsworth's phrase, "We feel that we are greater than we know," as the surface of such a river might feel when it found itself taking new paths, uprooting old obstacles, doing new deeds which were its own and yet not its own. Enough for the present of the suggestions herein contained; but the reader must not suppose that they refer *only* to the achievements of genius or of rare personalities, and that they therefore do not concern us in our study of the average, normal, commonplace manifestations of mind.


THE VISION OF ST. HELENA
From the painting by Paul Veronese

That, precisely, is the error which our modern view corrects, and replaces with a truth infinitely more noble and hopeful. The old view seemed to discern inspiration from without in the case of exceptional people. We now attribute their exceptional deeds to inspiration, inflowing, uprush, not from without but from beneath and within; and the priceless part of this truth is that all minds are essentially similar in this respect.

They all have depths beneath the surface of consciousness; and since mind is mind, all those depths are ultimately continuous with mind at large—the "Great Deep" in our image of the river. This is the doctrine of the "Constant God" that is in all men; it is the doctrine implied by the comparative form of the adjective in Carlyle's great definition of genius, as

"the clearer presence of God Most High in a man;" and its lesson for the practical psychologist is to despair of no man, to look for the Divine everywhere.

Despite our warning as to the necessity of beginning the study of psychology with simple and even humble matters, it has been impossible in this introductory chapter to refrain from the attempt to state adequately the scope and the promise of the superlative science of man's mind. Every subject is entitled to such an introduction, and notably psychology, which has such incomparable vistas, but has to begin with such humble matters as simple sensations, the reflex action of the frog's spinal cord, and so forth. And especially must we insist upon this old-new conception of the mind as something vastly larger than consciousness, for a reason which has already been hinted at. When referring to the doctrine of Myers, that the doings of genius consist of an uprush into consciousness from the mental forces beneath its surface, we carefully included and underlined a reference to conduct, as well as to poetry, philosophy, music, or what not. And in the next link of our argument we insisted that what is true of genius is true of all men—only that genius makes the truth more evident.

The Place of Behaviour Under the New Conception of Psychology

This prepares us for our culminating assertion, which is that the new psychology is above all, perhaps, the science of conduct. We are to think of the mind as a whole, we are to see that the living of a beautiful life in conformity to some ideal, and the painting of a beautiful picture in conformity to some ideal, are comparable and similar achievements of the mind, and depend upon the same laws. As Walt Whitman once admirably said: "Behaviour is the finest of the fine arts." Let anyone live for a week with a true artist in this particular field, and he will agree; even creative music must play second fiddle for him thereafter. Matthew Arnold's remark about conduct, and how much of life it is, finds new justification today. Conduct is not merely three parts of life—it is really the whole of life. Even the doings of the artist, rightly understood, are conduct, and depend upon his conduct and his own life and character and mind, his choice among things, his selection of one and rejection of another, his personal surrender to an ideal, and his conduct in following it—above all, his conduct in deciding whether he shall endeavour to be famous or to be great, admired or admirable.

Plainly, we impinge upon ethics, the science of right conduct. Indeed we do. Psychology and ethics are inextricable and indissoluble. The attempt to divorce them, and the parallel attempt to divorce art and morals, as if writing a poem were not part of a man's conduct, like writing his own name, or someone else's, to a cheque—these are ridiculous and contemptible in the eyes of science.

Psychology Above all Things the Science of the Whole of Conduct

Psychology is, above all, the science of conduct, which means the whole of conduct, and not any selected part of it; a science which has to study the conduct of a man's spinal cord when he wills to walk, and of his *cortex cerebri* when he wills to paint a noble or a vile picture. We are, then, expressly to conceive of psychology as the science of conduct, in the widest and fullest sense of that word. It is definitely not the science of consciousness, which is only the visible, the self-seen, surface of the mind, and which affords little clue to the "hidden springs of conduct," as the excellent metaphor of common speech calls them. We have to study consciousness, of course, and as closely as possible, but once and for all we see it now in its true relation to the whole of mind. We shall learn what only the saints and ascetics have known hitherto—that consciousness can be determined, that we can and do control and decide what shall and what shall not come to the surface of consciousness; so that even consciousness has to be conceived largely in terms of conduct.

The Capacity to Decide what We shall be Conscious of

In our study of dreams we shall see how Professor Freud, of Vienna, has shown that, during the waking life, we are constantly deciding what we shall, and what we shall not, *be conscious of;* and only when we become "unconscious," and personal self-management and conduct are relaxed in sleep, do our dreams reveal the nature and scope of the thoughts, wishes, memories, which we had been deliberately keeping beneath the surface of consciousness all the day—deliberately, though unknowingly. Introspection could scarcely reveal this fact, though it may give occasional glimpses of it. The modern methods of physiological psychology have revealed it, and thus furnish a striking illustration of the truth that psychology is the science not

of consciousness but of conduct, which is so deep and potent a thing that it underlies consciousness and largely decides what consciousness shall be—of what it shall be conscious.

And just as we reject the definition that psychology is "the science of consciousness," so we reject the definition of it as "the science of experience." Clearly that must be so, unless racial experience, the whole sum of things remembered by mind, and changes wrought in it by the whole history of life, be included. A boy becomes a man and falls in love—a tremendous psychological fact. But how can we explain or name it in terms of "experience"? He has no experience; nothing in his past gives him any clue to what is happening. This is a manifestation from depths far beneath the levels of experience or consciousness.

And just similarly does the definition of psychology as the science of experience fail us when we look at any of the doings of genius, which daily make experience ridiculous. No psychology is worth a moment's attention which leaves out everything that matters. The pyschologist wants to know why and how living creatures behave as they behave—which is indeed to answer the question why they are what they are. Above all, he wants to answer this question for himself and for his species. He quickly learns, as Dr. McDougall says, that "though conduct seems to be in great part determined by our sensations, feelings, desires, emotions, and all those other varieties of states or processes of consciousness which introspection discovers and distinguishes, psychology finds itself compelled in an ever-increasing degree

THE REALITY OF CONVERSION—ST. AUGUSTINE AND HIS MOTHER, ST. MONICA
From the painting by Ary Scheffer in the Tate Gallery, London

to recognise the co-operation in all mental process of factors that are unconscious, and so cannot be introspectively observed. . . . To define psychology as the science of experience or of consciousness is therefore to exclude the study of these unconscious factors."

Finally, let us be clear in rejecting the theory of Huxley and many others in the latter half of the nineteenth century, according to which the mind may be ignored because it makes no difference. If nothing affects conduct, if the organism must behave as it does, just as an atom or an engine must behave as it does, according to the physical laws of dynamics and chemistry; if, in short, the physiologist always has the last word, and people really behave as if they were machines, and according to the machines that they not *have*, but *are*—well, then, let us return to our physiology and anatomy, which alone matter, and trouble ourselves no more with the high-sounding names of what makes no difference. If your friend, your lover, your child, your hero, yourself, act simply in terms of nervous organisation, the chemistry of the bile produced by the particular liver in question, and so forth, let us stick to nerves and livers, for only conduct matters; and if they alone determine conduct, they alone matter.

Descartes' Theory of the Body as a Penny-in-the-Slot Machine

This theory really begins with Descartes, a masterly thinker, though not a great man, who wrote partly in terms of what he believed and partly in terms of what he thought would please powerful people. He invented the idea that animals are automata, or, in a word, machines, which act in a fixed way in fixed circumstances, according to their mechanical constitution, just like any penny-in-the-slot machine of today. No one who had ever kept a dog and observed how its experience affects its conduct could subscribe to such a view, and yet it is a very plausible view when you are tracing out the nervous paths in the spinal cord of a dead dog; and, indeed, probably no one can go through a course in physiology without a period during which the theory of the organism as a machine seems true. It is true, of course, but not the whole truth.

In his famous "Essay on Animal Automatism," Huxley went logically forwards from Descartes' position, as he was bound by his evolutionary beliefs to do. Descartes no doubt saw clearly enough that, if a dog is really an automaton, so is a man, but that was not safe to write; and he saved his face by inventing the view that man differed in having a soul, which was somehow attached to his brain and the rest of his body by means of a minute structure in the brain which is called the pineal gland. We know now that this pineal gland is the degenerated remains of a third eye, further traces of which are found in some lizards, but Descartes believed, or pretended to believe, that it was a special feature of man, and the seat or the point of action of his soul.

Huxley's Application of the Descartian View to Man as Well as Simpler Animals

Huxley brushed all this nonsense aside, and relentlessly proceeded, on sound evolutionary principles, to apply the Descartian view of the lower animals to man. It is the view that "if we could completely describe the structure of the nervous system of any man or animal, and had a complete knowledge of the laws of the physical and chemical processes that occur in it, we should be able to account completely for all the conduct of the individual." This means that our consciousness, ideas, wishes, feelings, perceptions, ideals, do not affect our conduct, but are simply the products—nay, the by-products—of the nervous processes, physical and chemical, which are occurring in our brains. This view does not exactly deny the existence of mind, for obviously no one can deny the existence at any rate of consciousness, but it amounts to much the same, for it denies that mind does anything; and what does nothing is nothing. It is the view of mental phenomena—a word which literally means "appearances"—as merely a sort of illusion that accompanies the essentially automatic behaviour of the brain, as if the slot machine was conscious, and thought that it chose to release the chocolate, whereas really the penny and the machinery did everything, and the machine's awareness of what was going on made no difference.[b]

The Perfect and Final Absurdity of Nineteenth Century Materialism

This awareness of the machine, as it worked, would not be worth calling even a phenomenon—the appearance of the chocolate would obviously be the phenomenon—but we might go so far as to call it an epi-phenomenon, a side-product that just happened to happen. Epi-phenomenon, we have already seen, was indeed Huxley's word; and in it we have nineteenth century materialism logically presented in its perfect and final absurdity.

The reasoning was all right; there must plainly have been something wrong with

the premises; and we who have followed Bergson and the great thinkers of our own time see clearly where the error lay. Mind, which for Huxley and the materialists was a by-product of the machine, is, for us, its maker; the machine is *its* machine, made palpably for *its* purposes. The mind of man, or the Mind that is in man, made the automatic machine that we call his body, and uses it, just as the mind of man made the penny-in-the-slot machine, and uses it, when a man wills to spend a penny on what it contains. In truth, the automatists cannot even explain an automaton, we see, without invoking mind, though for a generation they almost persuaded us that all mind can be explained away as a sort of creaking noise that accompanies the working of an automaton. Strange delusion, indeed, yet perhaps a necessary one to state and explore and explode, in the advance of knowledge. We have examined the machine and been very nearly hypnotised by it. Having rubbed our eyes and looked again, let us devote ourselves to studying ***the god in the machine.***

THE ALL-CONQUERING SOUL. "THE RIDER ON THE WHITE HORSE," BY G. F. WATTS
Reproduced by permission of Mr. F. Hollyer

MALARIA, THE DREAD DISEASE WHICH OUR NEW KNOWLEDGE OF DRUGS IS OVERCOMING

This fine picture, symbolising the gloom thrown over human life by the approach of the dreaded malaria, is by the French artist Ernest Antoine Auguste Hébert. One of the modern discoveries about drugs is the power of quinine to destroy the parasite of this disease.

THE NEW SOURCE OF DRUGS

The Appalling Folly of Taking in Ignorance Medicines Only Recently Understood as Dangerous

POTENTIALITY OF THE ANIMAL KINGDOM

In the last chapter we traced the origin, in the nineteenth century, of a new science called pharmacology, the first epoch of which may be defined as chiefly destructive. It taught us that a host of supposedly valuable drugs were useless, and that many more were harmful always; and, in conjunction with the new science of pathology, founded by Pasteur's discovery of microbes as the chief cause of disease, this study of drugs taught us also that the popular remedies, so long in vogue, at best only treated these symptoms, and left the underlying causes of disease untouched. We hinted, however, that a new era has to be acknowledged, in which the science of drugs begins to construct as well as to destroy, and that this realm of construction is found to be in the animal kingdom—after the vegetable and mineral kingdoms have been pretty well ransacked and found wanting.

From the oldest times until the rise of modern medical science, drugs or substances of animal origin had been very largely used by the medical profession. According to the old doctrine of "signatures," one wandered about a field or shrubbery, picking out a leaf of some quaint shape more or less suggesting an animal organ, and then used decoctions of that leaf for supposed maladies of that organ. If that was regarded as sound reasoning, obviously there was something to be said for actually giving doses of the liver of an animal to a human patient whose liver was supposed to be out of order. We must remember, also, the old psychological theories, familiar to every reader of the Bible, according to which certain facts of emotion and desire had their seat in certain bodily organs, such as the liver, the kidneys, the "bowels of compassion," and so on. Here, again, was an argument for administering drugs of animal origin to ill people; and if any further motive was needed, there was all the influence of classical augury, in which the entrails of animals were consulted for decisions as to, say, naval engagements and personal matters as well.

All these notions are now simply part of the history of ignorance; and the time came when doctors began to abandon the use of animal drugs, on account of their palpable failure. It is quite impossible to describe here the unmentionable combinations of animal products that were compounded and regularly used as drugs in the Middle Ages; and if we marvel at their very frequent and very excessive offensiveness, we must remember that there was also a view of disease which regarded it as due to possession by evil spirits, so that vile and horrible drugs were often administered simply in order to disgust the evil spirit with its abode, and effect its departure. When the development of modern science, after the revival of learning, began to discredit all such notions, and when the advance of chemistry gave physicians a variety of new drugs derived from the mineral and the vegetable kingdoms, all these horrible animal messes were largely abandoned.

Yet, if the reader will remember the scientific argument against the probability that vegetable drugs will cure our diseases—namely, that the chemistry of the plant is irrelevant to the chemical processes of man—he will also see that the chemistry of the bodies of animals must surely be very closely allied in many ways to the chemistry of the human body. We should reasonably expect that, if only the resources of the body of some animal, say a sheep, which is a mammal like ourselves, could be applied to ourselves, they might, for instance,

just contrive to supply a deficiency in our own chemical resources. And that is exactly what has been found.

Consider, for instance, the malady of development which is called cretinism, and also the disease of adult life which is called myxœdema. These diseases and some others are now all included under the excellent general term of athyrea (where the *a* is negative, as in atrophy or apathy), in order to indicate that they are due to deficiency in the action of the thyroid gland in the neck. Once we learn, according to this theory, that certain kinds of imbecility, hitherto absolutely hopeless, are due to defective production of certain chemical bodies by the thyroid gland of the patient, the ancient principles of animal therapeutics, so long dead, spring to life again. We kill a sheep and remove its thyroid gland, which we thereupon administer to the cretin child, and the imbecile becomes educable, intelligent, human. The drug is relevant.

The Triumph of the Antitoxin Treatment in Diphtheria, and What it Suggests

That was one of the two great therapeutic triumphs of the last decade of the nineteenth century. The other was the antitoxin treatment of diphtheria; and as in the first instance man applied in his extremity to the thyroid gland of the sheep, so here he applies to the blood of the horse. If the poisonous juices, or toxins, of the microbe of diphtheria be brought into relation with the tissues of the horse, those tissues—perhaps the white blood-cells, perhaps something else—produce an antitoxin, which neutralises the poison; and the production of the antitoxin far exceeds the need, so that in a short time not only is all the toxin in the horse's blood neutralised, but there is also present a great excess of free antitoxin. By no other process yet known can this antitoxin be produced, for no chemist in his laboratory yet has the clue to the inimitable and subtle chemistry of the life of the horse, whereby this antitoxin is produced. A child is in the grip of diphtheria, which is clutching at its throat and about to choke it. The child's body is behaving exactly like that of the horse, and producing an antitoxin, but not quickly nor abundantly enough. Let us now reinforce the child's insufficient antitoxin with some of the surplus in the horse's blood. The result is almost instantaneous. The whole meaning and significance of diphtheria have been transformed. The death-rate has been reduced *in exact proportion to the stage in the case when the antitoxin is applied*; no child treated on the first day ever die, scarcely any treated on the second, and so on. The drug is relevant.

We are dealing with these matters, very briefly, somewhat out of their place, since only by their aid can we convince the reasonable mind of the folly and absurdity of drugging, as ordinarily practised, by the public upon itself, and also by unwilling doctors upon the public. Only those who know what rational therapeutics depends upon and achieves can realise how irrational and disastrous must be the kind of ignorant and irrelevant therapeutics which not merely survives in our time but is actually multiplied a thousandfold, thanks to the pleasantness and accessibility of drugs under modern conditions.

The Very Small Number of Drugs that are of any Real Use

But let the reader bring his scientific judgment to bear upon the facts as we have placed them before him. Let him contrast the relevance of diphtheria antitoxin, for the diphtheritic throat, with the ludicrous irrelevance of this or that infusion from China or balsam from Peru. And here also we shall see another reason why the increase in the number and variety of drugs employed by the public upon itself is directly opposed to the progress of science.

For, as workers daily elucidate the real causes and nature of disease, so the domain of really respected drugs is being steadily narrowed down to a certain number which, to adapt Milton, are fit and fine though few. The total number of diseases, properly so-called, considered from the point of view of their causation, is very small.

The Cause of a Disease the Only Key to the Cure of it

There may be hundreds of names denoting as many symptoms; and anyone who remembers a few words of Greek can discover new diseases, and give them names, by the dozen, so long as symptoms are called diseases and causes are ignored. But causes matter everything, for only causation will give us the key to cure. Now, as there are really few diseases, though countless symptoms—probably, indeed, as many symptoms as there are people, for we are all different, and react differently to similar things—it follows that there need be but few drugs that really cure. One for each disease would be quite enough! Thus the tendency of the pharmacopœia is from the many and generally useless to the few and useful. As long as all the maladies due to thyroid

sufficiency, or "athyrea," were not understood, hundreds of drugs would be used to combat them, and every new one would be welcomed for its possibilities. Reduce all these maladies and their quite innumerable symptoms to thyroid insufficiency, and instantly you sweep away a shopful of irrelevancies with a single relevant substance.

The Downfall of Drugging and the Triumph of Really Relevant Drugs

Let us be clear where we are, then, for unfortunately there are plenty of people ready to pounce upon any condemnation of the older methods of drugging, and thence to argue that only Christian Science, "psycho-therapeutics," or what not, is a remedy for human ills. It would be no service to anyone in the long run if that were the conclusion from the arguments of the last and the present chapters. Thyroid extract is, of course, a drug. Diphtheria antitoxin is a drug. Nothing could be more untrue than the statement that the most competent physicians use no drugs nowadays, or have no faith in them. But it is true that, where their predecessors used scores of drugs, such physicians will scarcely employ more than a dozen, of which, perhaps, neither their predecessors nor the present public have even heard. Again, antiseptic surgery is the triumph of a drug carbolic acid—but, again, a relevant drug, deliberately selected for its known poisonous action upon the microbes which cause surgical inflammation. Our phrases, then, must be chosen with circumspection; we certainly cannot speak, as some have done, of "the decadence of the drug," but we certainly can speak of "the decadence of drugging." There is all the difference in the world. And if we include among drugs, as we must, the whole series of antiseptics and anaesthetics, together with antitoxins, vaccines and sera, and other substances of animal origin, then certainly the present age of medicine displays what may properly be called the triumph of the drug. Only it is a triumph of this kind—that those who best understand and most profit by it are the most sparing and fastidious and infrequent in their recourse to it.

The Body only Adapted for the Consumption of Food—not of Drug Poisons

The future of drugs, in their scientific employment, demands our attention, and then we shall be fully prepared for the practical moral. No modern physician of the first rank now writes the sort of shot-gun prescription with which so many of our forefathers were peppered and slain. We recognise now that any drug must be regarded as a poison until the contrary is proved and the contrary never is proved. What, indeed, happens is that successive inquiries condemn as poisons many substances which we had supposed to be innocuous, like the boric acid which is added to milk and cream and butter, or was until recently, and the saccharin which people take instead of sugar. The body is not adapted for the chronic consumption of anything but *foods*, nor is there any reason why it should be. We have learnt that even invaluable drugs like quinine are essentially poisons. Professor Metchnikoff has lately insisted upon the fact that this drug tends to paralyse the white cells of the blood; and every doctor, and many patients, know how liable it is to cause toxic symptoms associated with the sense of hearing. Fortunately, the drug is much *more* poisonous to the parasite of malaria than it is to us, and hence its main value for us.

The Danger that Lies in Drugs that are Really Useful

So far as drugs for producing particular effects upon the body are concerned, we have yet to find those which are without risk or danger. The ideal hypnotic, the ideal antiseptic, the ideal anaesthetic, do not yet exist. Those with which the public experiments upon itself so freely do not answer to the description. The antiseptic which is so general in its action as to kill microbes in general is also, and therefore, so general in its action as to kill living cells in general. The public may be persuaded to swallow boasted antiseptics, in consumption and the like, so as to kill the microbes, just as the medical profession ordered antiseptics like creosote for consumption ten or fifteen years ago. But we now know that, if the general antiseptic is efficient, it is also deadly to the patient's body; and if it is indeed harmless to the patient, it is harmless to his enemies. The future, in this case, lies with the special antiseptics so made as to kill or neutralise special parasites or special poisons, and without any other action. The diphtheria antitoxin is a case in point.

As regards anaesthetics, the public must not suppose that we yet possess anything which is safe for the amateur to employ. People may take chloroform or ether, in small doses, whether by inhalation or by the mouth, for long periods, just as they take the third anaesthetic, alcohol, which is so often combined with them in the "A. C. E." mixture, but doctors know that the effect upon the brain is very serious indeed, and

that such treatment is a remedy worth having for no disease or symptom whatever. There is no ideal anæsthetic and no ideal anodyne. We seek in vain for a drug which will relieve pain, headache, or backache, or anything else, and do no harm. Medicine and chemistry know nothing of such a drug, though they know many that may be used with caution, on special occasions, for short periods. But the public assumes that the ideal anodyne, unknown to science, really exists; that it is possible, for a few pence, under any fancy name, to purchase a drug which is so powerful that it will arrest the functioning of an irritated nerve-cell, and yet so innocent that it will do that nerve-cell no harm. The belief is absurd, but millions of people act upon it every day.

The Ideal Hypnotic Not Yet Found, and Not One Fit for the Public to Help Itself To

The case is exactly the same as regards the ideal hypnotic. It does not exist. No doubt German chemistry has done great things in this direction within the last two decades; and in the absence of opium the practitioner is no longer left with chloral alone as a substitute. What we need, however, is a hypnotic which produces the hypnotic effect, and no other, and never loses it. We may yet discover such an hynoptic in the animal kingdom, but meanwhile the verdict, here also, is that there is nothing which is fit for the public to help itself to without medical supervision. The law, or Privy Council regulations, in this matter should be strengthened.

So far as the actual cure of disease is concerned, the future belongs to the animal kingdom, so long neglected; and if we believe in the *vis medicatrix Naturæ*, we can hardly be surprised. The healing power of Nature is effected, in the animal body, by animal substances; the thyroid gland will cure or prevent cretinism, the white cells of the blood produce substances that destroy microbes, and so on.

The Only Safe Course—Not to Take any Kind of Drug Without Advice

The new medical science simply takes the hint from Nature, and applies with intelligence the substances with which she has been preventing and curing disease ever since pain and death first came into the world. This is the proper reply to the unfortunate cranks who inveigh against, say, the antitoxin treatment of diphtheria as unnatural. Nothing short of leaving the patient to die could be more natural.

The object of all the foregoing, for the lay reader, has been to justify up to the hilt the practical conclusions at which we are bound to arrive in the interests of hygiene. From the nature of the case, we now see, the drugs which so many of us consume are incapable of curing our disorders, and can, at most, do no more than mask them. Let the reader be specifically warned against all drugs that contain opium, morphine, chloroform, ether, or alcohol, whether openly, as a few do, or secretly, as many do; against the most accursed drug called cocaine, which is now destroying so many lives in the United States of America especially; against chloral, chloralamide, trional, tetronal, sulphonal, paraldehyde, veronal, and all other hypnotics ending in -al, or anything else; against antipyrin or phenazonum, antifebrin or acetanilid, phenacetin, exalgin, antikamnia, chlorodyne, and their congeners, one and all. The results of taking these things, none of which is a *cure* for any known disease, are only too often horrible in the extreme; and their nature is such that the only safe course is not to begin their use. They attack the centres of self-control or inhibition, and there is little hope or help when these are captured.

The Evil of Handing Prescriptions from Patient to Patient

Many of these drugs have their uses on occasion; and if they be freely given it is possible for the doctor to gain the temporary gratitude of his patient by their employment, but the risk of prescribing them, except in the most rigidly limited way, is one from which the conscientious practitioner must always shrink. Though they are sometimes useful, so are arsenic and prussic acid, but it is really more necessary that their employment should be limited and under responsible control than in the case of these two notorious poisons. This is not at present the case: but all these things, and many besides, should be scheduled poisons, which they really are, and should be prescribed as such. It ought also to be impossible to repeat such prescriptions without the doctor's order, and absolutely out of the question that the prescription should be handed from one patient to another. The popular view is that the doctor's objection to this practice is monetary. It makes no difference to the present writer, but he condemns it without reserve. It is hard enough for the doctor to know what to prescribe for the individual patient, for each case, he knows, is really unique. It is quite impossible for those who have no

knowledge at all to say that the prescription which suits one patient is suitable, or even safe, for another. As for the drug habits which have been started in just this way, their name is legion.

So much for those recognised and official drugs, of which the dangers, unfortunately, are so little recognised. And now let us return to the general conclusion which has been asserting itself all along · that the drugs of the future will be obtained from animal sources. We have quoted two great illustrations, and the reader must already have observed that his own body is manufacturing "thyroid extract," that marvellous drug, for itself all the time, otherwise he would either be a hopeless fool, by no means reading these lines, or, if he were producing no thyroid secretion at all, he would almost certainly be dead. Similarly, though his body is not producing diphtheria antitoxin at the moment, that is merely because, in all probability, he is not just now being attacked by the diphtheria bacillus—or it would be doing so. The meaning of all this is clear. If we find that, for drugs that are really worth talking about, we have to abandon the vegetable and mineral kingdoms, and search the animal body, it is clear that the *vis medicatrix Naturæ*, long worshipped by the wisest of the ancients, has taken bodily form at last.

The Really Curative Drugs of the Body's Own Making

Modern science finds this mystic power incarnate in the living body, and its instruments can be isolated, handled, weighed, and tasted. In a word, the really curative drugs are of the body's own making, nor, with a rare exception or two, are they to be purchased at any chemist's shop. We are only beginning to isolate these drugs, and little enough is known about them. But at least the modern physiologist knows that the greater part of any serious discussion of personal hygiene, such as this present one, is really concerned with the production and employment of these curative, *and preventive*, medicines in and by the healthy body. The writer of the treatise may not know it, nor may his readers. Yet that is what they are really discussing and aiming at all the time. He tells them to breathe open air, because experience shows its value; but his successors, a generation hence, may be able to isolate, from the body, the exact chemical substance which is best produced by it under the influence of open air, and which antagonises disease—say, by making the body uninhabitable by the microbe of consumption. Thus the reader who now attends to the advice already given regarding open air, or on many other points, is favouring beyond a doubt the conditions under which the protective and curative substances are manufactured, dispensed, and administered in and by his own body, which is far and away the wisest and most accomplished of manufacturing chemists, and incomparably superior to any doctor in the diagnosis of its diseases and their treatment.

How the Healthy Body Makes Drugs to Keep its Own Health

All this is so important and so radical in our modern conceptions of hygiene, and so entirely condemnatory of the practice of self-drugging, which still spreads every day, and from which we desire to exclude every reader of POPULAR SCIENCE, that a few illustrations must be cited. They range from trifles to the most mortal diseases. Thus, the healthy nose secretes an antiseptic mucus, which largely kills objectionable microbes, such as those which produce a common cold, influenza, or pneumonia. The healthy blood contains antiseptic substances which must frequently be called upon to destroy the microbes of consumption. We have evidence that the greater number of all people have been attacked by consumption during the course of their lives, and have rapidly recovered, probably without any idea of what had happened. The recovery was due to the body's own antiseptics. If the doctor tries to add antiseptics to the body for this purpose, he always fails; and on the day on which the researchers isolate, in the body, the substance which it makes for its own protection against the tubercle microbe, and succeed in giving it to patients without destroying its powers *en route*, on that day all cases of consumption will be curable and will be cured.

The Natural Antiseptics which are Produced by the Body to Kill its Enemies

The healthy stomach—but observe that we speak always of the *healthy* nose, the *healthy* blood, the *healthy* stomach produces an acid, commonly described as a "mineral acid," called hydrochloric acid. It is the acid constituent of common salt, for instance, and is really a most strange and surprising thing to find produced in the living body. It is of value in digestion, and will require further discussion when we search the problems of dietetics. Yet it is far from being indispensable for digestion; and the kind of digestion which it performs,

or, rather, facilitates, is far better performed in the bowel with the aid of a powerful alkali. Yet this acid is always formed in large quantities by the healthy stomach, which is richly provided with millions of living cells that exist solely for this purpose. Now, hydrochloric acid is an antiseptic, and has long been known to kill various yeasts and other fungi, which may be swallowed in the food, and which multiply in the stomach, causing tragic dyspepsia, if the hydrochloric acid is not properly formed. Conventional physiology has long regarded this as a fortunate accident—an opinion in which the present writer has never concurred, considering how very subordinate is the use of this acid for any other purpose. The recent work done by the Tuberculosis Commission in this country goes far to confirm his view. Hydrochloric acid is the natural antiseptic of the body, or one of them, for there may well be thousands; and it daily saves us from all manner of infections due to the living organisms that we swallow in all uncooked or imperfectly cooked food.

The Spontaneous Cures that are Always Going On in our Bodies without our Knowledge

To these instances add the thyroid secretion, which is daily curing or preventing—either word will do—in each of us such diseases as cretinism and myxœdema; the pituitary secretion, which, by its right quantity and quality, is preventing acromegaly; the secretion of the adrenal glands, which is preventing Addison's disease; the invaluable internal secretions of the racial glands, without which we should not be ourselves. And now the most recent and authoritative work upon cancer is declaring that probably in very many people malignant growths are started, and then suppressed, by the resources of the body without anyone knowing anything about it; that the healthy body is constantly producing substances which are antiseptic, so to say, to the cancer cells which would otherwise develop in it, and that the "spontaneous cure" which is sometimes seen in cancer, and is probably far commoner than we know, is due also to the sudden determination of the body to rid itself of the invader. It is along these lines alone, as some of us have been maintaining for years, that the certain and constant cure of cancer will ultimately be achieved. Nothing more need be said on that subject now. The point is that, in the whole range of disease represented by the contrast between a cold and a cancer, the same principles are illustrated. It is by its own chemical products, made on purpose, inimitable in fitness, safety, variety, delicacy, certainty of administration, infallibility of diagnosis, that the body keeps itself well, controls insurrection, checks waste, neutralises poisons, destroys invaders, goes breast-forward, never doubting.

The Folly of Drenching the Body with Alien Drugs that will Probably only do Harm

That is the conclusion of modern knowledge. That is the fact which modern science seeks to elucidate and modern practice to apply; and in the light of that great conclusion, so new and yet so old, we must approach and censure, almost without reserve, the ever-increasing folly which drenches this house of life, so powerful and delicate, so wise and so heedful, with alien drugs which can rarely do it anything but harm. No doubt a new era is approaching. The present vogue of patent medicines cannot possibly survive the general establishment of national insurance, for it is not in human nature that the insured will drug themselves, as they now do, when they are contributing to the ever-available supply of doctoring and medicine for themselves. But our say must be said, if we are to carry out a leading principle of this section, which is to warn the reader against all manner of poisons; for alien drugs in general, like the gases of foul air and the products of over-eating, fall within the category. Perhaps in what is primarily a work of science we should be brief in our reference to this matter; yet there are many facts which science alone can clear up and estimate, such as any man of science who has any feeling in him is bound to state and to condemn whenever Heaven gives him opportunity.

How People Who Drug Themselves Pay Ten Times the Cost of the Drugs they Use

Patent medicines are largely consumed by people of small income, and therefore the question of their cost is important. That is the first objection to a very large number of them, of which the only active principle is aloes, and which may often be very useful indeed. The great malady of civilised life among the sedentary is constipation. We shall see, in due course, what are its causes and the proper ways of dealing with it—ways simple and pleasant and certain. But at present the public is not instructed in these matters. The children do not learn about them at school, and, no doubt, the present work involves the most extended and comprehensive instruction of the public in these scientific matters of personal moment that has ever been achieved hitherto. Such

being the state of the popular mind, and such being the demand of the sedentary bowel, of course there has sprung up a great supply of aperient medicines, very rarely departing far from aloes as their staple. This is an excellent drug, and every doctor employs it. But there are two objections to the popular use of it in this way. In the first place, aloes is a very cheap drug, and there is no good reason why people who can afford no luxuries should pay ten or fifty times the fair price for a combination of, say, aloes, ginger, and sugar. That is clear enough.

Drugs that May be Used Occasionally, but Become Harmful if Used Habitually

But a graver objection to self-drugging, even with such inherently harmless substances as aloes, and even for states of the body which require some such attention, is that every drug may be administered in a right way or in a host of wrong ways. Every textbook on therapeutics points out that aloes is an unsuitable drug to use habitually in chronic constipation. Its action is not tonic upon the flabby bowel, and it leaves the bowel with a greater tendency to constipation than ever. Therefore the wise doctor employs it only for special and exceptional purposes, not meaning to repeat the dose, and not expecting to have to do so; and he carefully avoids it as a remedy for a condition which will be certain to recur in a few hours, for he knows that it merely relieves a symptom, and does nothing for the underlying cause. As a matter of fact, the persistent use of such a drug as aloes, or any other which increases the flow of blood through the lower portion of the alimentary canal, is very apt to lead to permanent congestion of the veins, which means the too-prevalent and tiresome malady called hæmorrhoids, or piles. That is a simple illustration of a minor evil often due to the practice we here condemn.

The Diabolical Drugging that Pretends to Deal with Nervous Disorders

A clear remedy is a statutory requirement that the composition of all these preparations shall be stated upon the bottle. A more profound remedy, and perhaps a more practicable one, though terribly slow in its operation, is the education of the public in these matters. Most urgent of all is the case of the remedies which are bought for the lungs in consumption. It is difficult to know how the gorge of any humane and honest man can fail to rise when he considers how thousands of poor consumptives, who need every farthing they possess for the purchase of pure milk and the obtaining of pure open air, are spending their shillings on preparations which are not merely worthless but owe all their attraction and their sale to the presence of large quantities of alcohol, which modern research has absolutely condemned in all forms and stages of tuberculosis, as we shall see in due course.

For, after all, the merely aperient preparations with which the public doses itself are the least of the evil; those which contain, in masked form, any of the neurotic drugs already mentioned are far worse, causing nervous disorders compared with which hæmorrhoids are pleasant. Yet there is a third class, calling for all possible reprobation. These are the drugs which are announced for the relief of nervous disorders, including those connected with the racial functions. The objection here applies much less to the mere drug than to the calculated suggestions of disease with which it is recommended, and to the grave mental results of those diabolically contrived suggestions.

The Need for Education in the Laws of Life and Health

If the reader knew what the writer's correspondence has brought him from victims of these things in many parts of the world, he would realise that this is an evil which calls for something stronger than words. Above all it calls for a higher standard of education and direction of young people of both sexes, *first* in the laws of life and health, and thereafter in anything else that matters.

Quite recently a long-standing demand has been at last met by the appointment of an official inquiry, with Sir Henry Norman as Chairman, into the whole question of the sale, nature, and effects of drugs of secret composition. This inquiry is bound to have important results, and the demand made by students of the subject is that already mentioned—that the composition of these preparations should be stated upon the label of every bottle. This will mean, however, the practical loss of monopoly in many cases where vast vested interests are involved, and it is very doubtful whether so much can really be hoped for. But nothing need interfere with public education; and the British Medical Association has lately done good service in publishing a convenient shilling volume, entitled "Secret Remedies," which has had a very large sale, and which states the results of analysis of a large number of these preparations, including the worst and the most popular.

THE CHEMIST AND A GRAIN OF WHEAT

The chemist in his laboratory is the wizard of the modern world. From a grain of wheat, by the processes of synthetic chemistry, he can build up a marvellous variety of substances such as are shown in this picture—starch, bread, soap, preserves, oil, fireworks, candy, rubber, paint, varnish, cattle-feed, sugar, syrup, and jelly

THE CHEMIST AS CREATOR

How the Skill of Man in Combining Chemically Separated Elements Outrivals the Productions of Living Nature

PROBING THE MYSTERIES OF LIFE

It is scarcely more than sixty years since man began seriously to rival the creative powers of Nature. He wanted a great many new substances, for various purposes, but it seemed as if he would have to want them. He had been able to break up many forms of matter, but the most useful of natural materials were apparently far beyond his power of creation. The substances were found only in living things; and, after long and vain experiments, men of science generally agreed that all the stuffs produced by the life-force could never be manufactured profitably, if at all, by artificial means.

Yet, out of curiosity, chemists went on in their purely destructive work of trying to break up everything they could lay their hands on. They had lost all hope of ever being able to rebuild in their laboratories the wonderful stuffs of life which they were continually burning and testing and trying to analyse. Still, it was a very interesting amusement, and the chemists continued their work of destruction, undeterred by the utter indifference of the public. They granted there was nothing to be gained by finding that starch and cotton were composed of the same ingredients, in the same proportions, or that sweet grape-sugar and the acid of sour milk were identical when they were broken into something that was of no use to anybody. The mysterious life-force, they admitted, was the only power that would turn a mixture of the elements of charcoal and water first into a foodstuff and then into a dress material. Then why do you go on with your work? said practical men. Well, replied the chemists, it is very interesting to find what living matter is made of; and even though we never get to the bottom of the problem, yet we may manage to add a little to the sum of human knowledge.

These chemists who destroyed the stuff of living things, by all sorts of ingenious means, were not encouraged in our practical country. There was apparently nothing in common between them and the really useful men of science, who kept to the study of metals and minerals and other things that could be made into new mixtures without the help of the mysterious life-force. Business men appreciated the achievement of chemists who worked out the manufacture of a saleable article from some waste mineral. But the few and far-scattered men of science who vainly tried to pry into the creation of living matter were not appointed to professorships of importance in Great Britain.

Now, however, the disciples of these few men hold in their hands the destinies of the human race. Without them, the people on our overcrowded planet would soon be compelled either to restrict the number of children to which they give birth, or to submit to a constant and increasing diminution in the supply of food. Happily, however, the modern chemist has won a larger power of creation than that possessed by the so-called life-force. Out of his long and apparently useless attempts to break down starch into the same elements as cotton, there has slowly been developed the opposite power of combining the elements of lifeless matter into substances exactly similar to those produced by plants and animals. The work of analysis has shown that the substances of our bodies, the fragrance of a rose, the stuff of life in a microbe, the fruit of an apple-tree, and all the bewildering variety of living products are chiefly based on combinations of four elements. The carbon that we find in coal is the foundation; the nitrogen of the air is also important, and so are the oxygen and hydrogen that are mixed together in water.

From these four elements, with admixtures of certain minerals, the substances of the living world are now known to be composed. There is no longer any difference between the chemistry of living stuffs and the chemistry of lifeless matter. Man has got control over the four elements with which the spirit of life clothes itself. He can do more in his laboratory than the life-force can in the plant and the animal.

How Mind has been Breaking Down Matter to Find its Elements

For instance, fifty years ago the organic compounds derived from animal and vegetable sources, such as sugar, starch, oils, fat, gums, and resins, could be counted only by hundreds. Today, however, their number exceeds one hundred thousand; and most of them are created in the laboratory of the chemist and in the chemical works which he has brought into existence.

Synthetical chemistry, as this extraordinary power of outrivalling natural forces is called, is still built on destructive work. Generations of chemists sometimes labour for a hundred years in pulling a well-known substance to pieces, in order to study the atomic structure of the elements composing it. A few years ago they succeeded in even breaking up the atom into a thousand parts, which they weighed and measured. But, having done this and reduced the entire matter of the universe into something quite impalpable, they have gone on to weld the broken atoms together into a multitude of strange and new combinations. It looks as though the spirit of life has been slowly working for many millions of years on this planet of ours, and fighting its way painfully and gradually into matter, trying to subdue it to its own high purposes.

The Dreams of What Might be Done if Mind Only Took Command

Countless ages have passed since it created the brain of man and made that brain its fittest instrument. Yet even then the power behind the instrument was very feeble. It had to rely on the play of natural forces; it followed these forces because it was not in a position to direct them. Only where natural conditions were very favourable was it able to display a little of its wonderful faculties. Merely in dreams did it feel itself the king of the material world; in its waking hours it found itself still the slave of matter. It was brutalised and starved, tortured and fettered, by the stuff that it wished to weave into an earthly garment of its own making.

Ah, those proud dreams that the spirit of man has dreamed in its hours of utter weakness! From the savage of the Stone Age, with his fairy tales of some magic power over Nature, to the alchemist of the Middle Ages, with his fancies of a philosopher's stone that would change lead into gold, and of a medicine of immortality that would prolong his life for hundreds of years, the baffled and yet creative human soul has consoled itself in the hour of its defeat with wild and romantic prophecies of its future triumphs.

And now, strange and impossible as it seemed only one hundred years ago, these prophecies are at last seen to have an element of truth in them. The magic carpet is a fact; the philosopher's stone is a reality; and, if Professor Metchnikoff can be believed, even the medicine of long life is well in the way of being discovered, and sold at a shilling a pint. Mr. Rudyard Kipling once said that "the wildest dreams of Kew are the facts of Kamtchatka," but it is much truer to say that the wildest dreams of Kamtchatka are the facts of Kew.

The Coming True of Some of the Wildest Dreams of Man

In Kew, men, if they like to take the trouble, can turn pieces of charcoal into real diamonds, and manufacture rubies and sapphires out of a pennyworth of emery. They can also change, if they will, one element at least into another, and fly through the air quicker than the fastest bird. They have a magic voice, by means of which they can talk with a man in Paris; and very soon they will be able to see through the walls of a thousand houses by means of a magic eye, to which an electric wire and a set of mirrors are attached.

A great deal of these victories over inert matter are the work of the modern chemist, armed with retorts and tubes, alembics, and electrical appliances. It is the chemist who has recently given man rays by means of which he can see through his own flesh, and drugs that enable him to conquer the most terrible of diseases.

Artificial building-stones in great varieties, artificial silks and other fabrics, furniture made of mud and chalk, food for plants obtained by electricity from the air, are a few of the creations of modern chemistry.

There can be no doubt whatever that the modern synthetic chemist will entirely revolutionise industry and agriculture. Many nations of the Orient are already suffering from the victories won over Nature in the laboratories of Europe. By a series of

researches lasting about twenty years a German chemist has swiftly and completely ruined the indigo industries of India, which in 1895 were worth £3,570,000 a year. As is well known, 90 per cent. of the total quantity of indigo now used in the various countries of the world is manufactured from coal tar.

At first, synthetic indigo was only an academic victory of the modern chemist. He took natural indigo to pieces, and found it was an arrangement of elements that could be extracted from napthalene. Then, having analysed the substance down to the foundation, he began to build it up again, and did, in fact, build it up completely. But the process was too slow and costly to interfere seriously with the natural production in India. There are many cases of this sort in modern chemistry. The man of science primarily seeks for the actual power of reproducing in his laboratory the living substance that he has broken up into its ultimate elements. It is the joyful exercise of his strange creative powers that leads him to give up the great part of his life to attacking a single problem. When he has solved it, and made a pennyworth of artificial indigo at a cost of thousands of pounds and many years' work, he has done with the matter. He leaves the use and the profit of his discovery to the manufacturing chemist, and turns himself to some new point of attack in the chemistry of living things.

It was a pure accident that changed the discovery of synthetic indigo into a vast German industry that ruined the indigo-growers of India. In a certain part of the artificial process, it is necessary to change napthalene into phthalic acid. This can be done by the action of hot sulphuric acid, but the method is very slow. All kinds of experiments were made with a view to quickening the action, and in one of the tests the thermometer used in registering the heat employed was accidentally broken, and the mercury fell into the hot mixture. The action of the sulphuric acid was strangely quickened by the presence of the mercury, and this curious accident suddenly brought about the desired improvement of the process. Possibly, if the bulb of the thermometer had not broken, the rich and happy indigo-growers of India would be still smiling at the costly synthetic product elaborated by a German chemist.

THOMAS EDISON, WITH WOODEN FURNITURE ON HIS RIGHT HAND AND CONCRETE ON HIS LEFT

There is another chemist, Komppa, who has seriously interfered lately with the plans of the Japanese Government. Komppa was interested in the composition of camphor in a purely disinterested way. Chemists had been attacking camphor for a hundred years, and they had attacked it vainly. Komppa continued their work as a matter of course, just as a biologist will continue the study of a special kind of sea-urchin by way of filling in his time and adding a brick or two to the temple of human knowledge. The interest which the Japanese Government took in camphor was more practical. In their war with China they had acquired the island of Formosa, the interior of which was inhabited by savages, and overgrown with camphor-trees. Japan needed money badly, and the Government was very intelligent and businesslike. After consulting with men of science and manufacturers it came to the sound conclusion that Formosa was better than a gold-mine. It was the only rich source of camphor in the world, and there was a great need for this substance in all civilised countries. It was especially needed in making celluloid and various kinds of explosives; and, instead of the supply growing with the new demand, it woefully decreased every year. All the great camphor forests of Borneo and Sumatra had been destroyed, and even in Formosa the industry was a dying one.

DR WILHELM OSTWALD

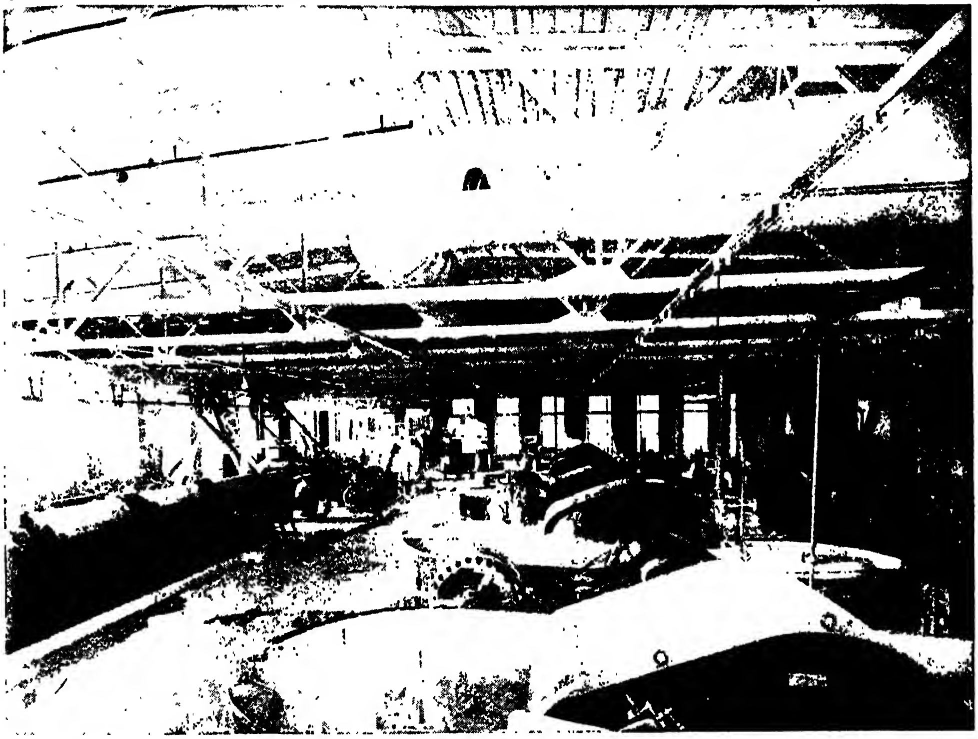
For camphor could only be made by cutting down the big trees and chopping up the wood and steaming the chips in furnaces. Only trees at least fifty years old were used for the purpose, and the production was running short for want of trees when Japan dispossessed China of Formosa. On the other hand, there were large tracts of camphor forests in the savage interior of the island; and as Japan was burdened with an enormous debt after the war with Russia, her Government resolved to use its monopoly in camphor in lightening the national debt. A series of military expeditions quelled the Formosan savages, and men of science and electrical engineers followed the troops, and surrounded the valuable forests with live electric wires. Very often the process of distillation was carried on with armed sentries watching over the labourers to defend them from the raiding savages.

Then, as the camphor-trees were practically exhausted in the settled districts, the Japanese Government began a scheme of reforestation on a huge scale. In 1906, 346,000 trees were planted; in 1907, 1,300,000; in 1908, 4,830,000; and in 1909, 5,060,184 trees were placed in the ground. Thus, by intelligent foresight and keen business talent, the Japanese Government apparently succeeded in creating a most valuable monopoly in a natural product which was absolutely necessary in various important industries in Europe and America. Photography and cinematography, the manufacture of imitation ivory for countless purposes, and the preparation of certain high explosives all depended on the monopoly established in camphor by the far-sighted, businesslike Japanese Government.

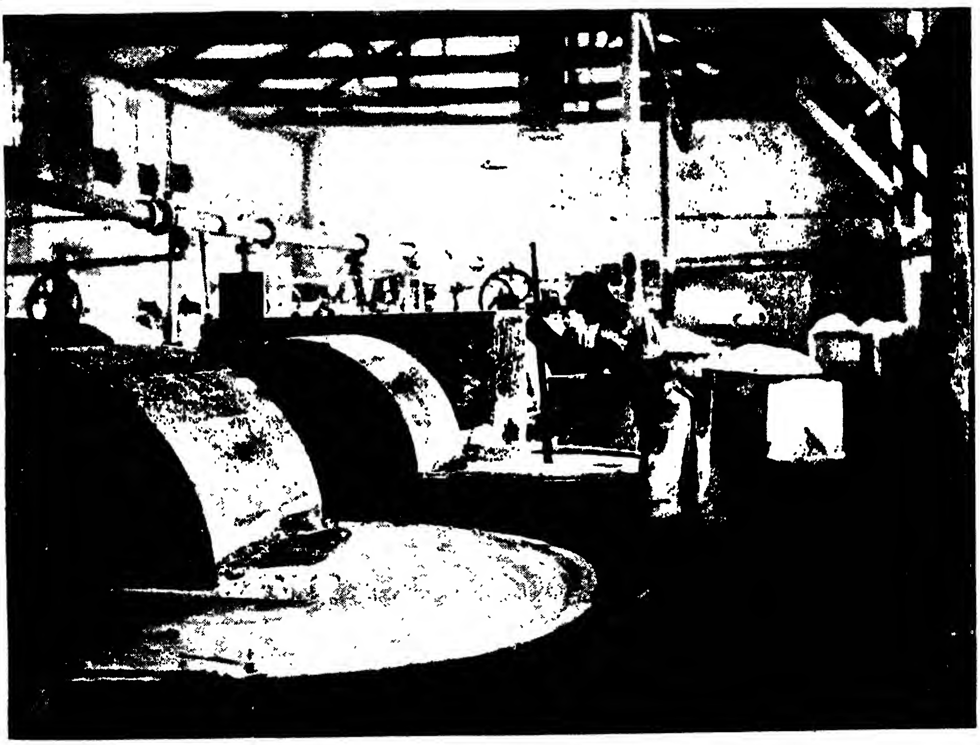
There was indeed a possibility of Japanese manufacturers benefiting by cheap home labour and nearness to the source of camphor supply, and building up a commanding position in the celluloid industry. In the meantime the Japanese Government began to sell their camphor on a rising scale. In about four years the price of camphor was increased by more than one and a half times, with great profit to the national revenue of the Empire of the Rising Sun. The increase in price enabled the Government further to stimulate its camphor industry by paying the producers a higher wage. Moreover, the general demand for camphor was not lessened by the sudden rise in the market price. So many new industries urgently needed the stuff that the supply was still inadequate.

It seemed as though the Japanese Government had obtained one of the most prosperous monopolies in the world. But, by the irony of fate, just when the Japanese in 1903 began to raise the price of natural camphor, Komppa completed the work on which European chemists had been engaged for one hundred and eighteen years. He synthesised in his laboratory the various elements of camphor. Industrial chemists then took up the matter, and in

THE BUILDING UP OF PAPER FROM GRASS



MACHINERY FOR BREAKING UP GRASS INTO PULP AND EFFACING ITS VEGETABLE CHARACTER



MIXING-TANKS, WHERE THE BLEACHED PULP IS CHEMICALLY COMBINED WITH SIZE AND DYE AND BECOMES MATERIAL FOR PAPER

1905 they were able to manufacture camphor at a price that prevented the Japanese Government from making the natural product dear. At present, a camphor identical in all ordinary and physical properties can be synthesised from oil of turpentine, and the manufacture of this chemical product is seriously interfering with the monopoly of the Japanese Government. Moreover, two English chemists have found that there is no need to wait till the camphor-tree is fifty years old, and then extract its camphor by destroying the wood. They have discovered a way of distilling from the leaves of the trees four times the amount of crude camphor obtained by destroying the growing tree. So young camphor plantations are now being formed in Jamaica, Africa, and Malaysia, the foliage of which can be at once used in competing in the camphor market with the Japanese Government, and with the synthetic chemists of Germany.

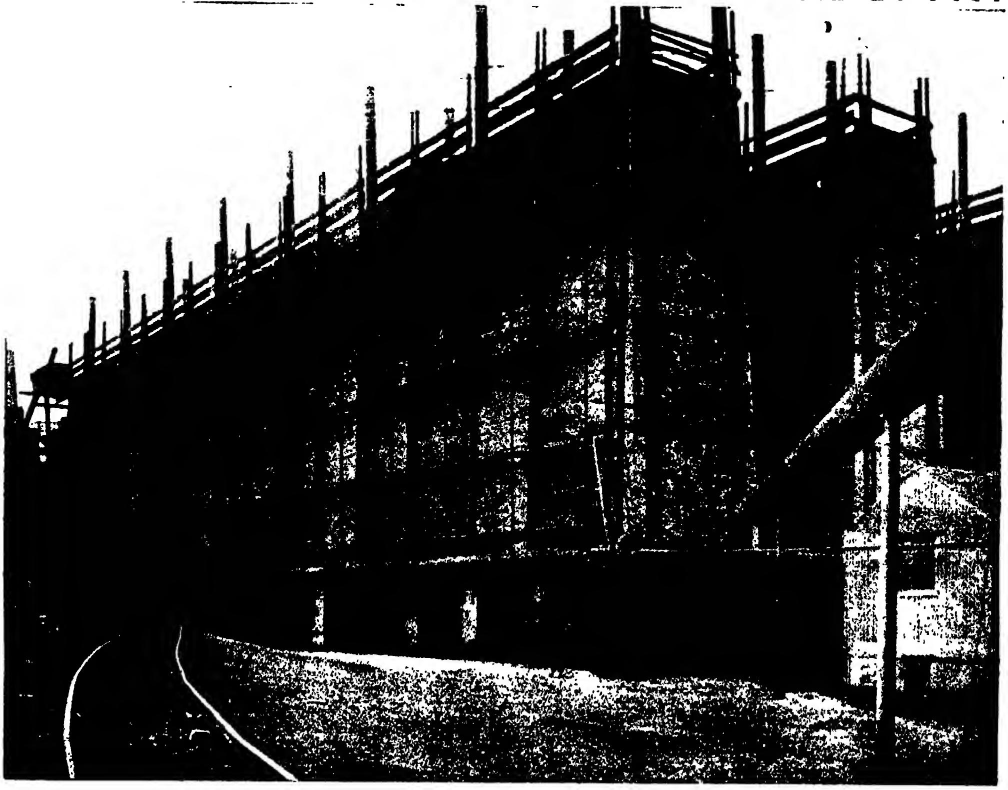
The synthetic chemist, however, is not yet beaten. He is now striving to obtain a cheaper and larger supply of oil of turpentine than can be got from pine forests. The chief constituent of turpentine oil is pinene. Now, pinene is a derivative of benzene, and benzene, as everyone knows, is obtained from coal tar. So synthetic turpentine is not beyond the creative powers of the modern chemist. Tremendous will be the revolution in industry when this is accomplished. For the cheap, sound, chemical turpentine will affect not only the camphor market; it will produce on the rubber plantations of the world an effect similar to that which synthesised indigo produced on the indigo-fields. There is no difficulty even now in preparing rubber from turpentine, but the process is too wasteful for commercial use. But when the chemist can provide the raw material in cheap abundance, synthetic rubber will become the basis of an industry of vast importance. Rubber has become a general necessity. The modern world moves on rubber wheels, and many new uses can be found for the elastic material as soon as its production is cheapened and greatl increased.


PIERRE EUGÈNE MARCELLIN BERTHELOT

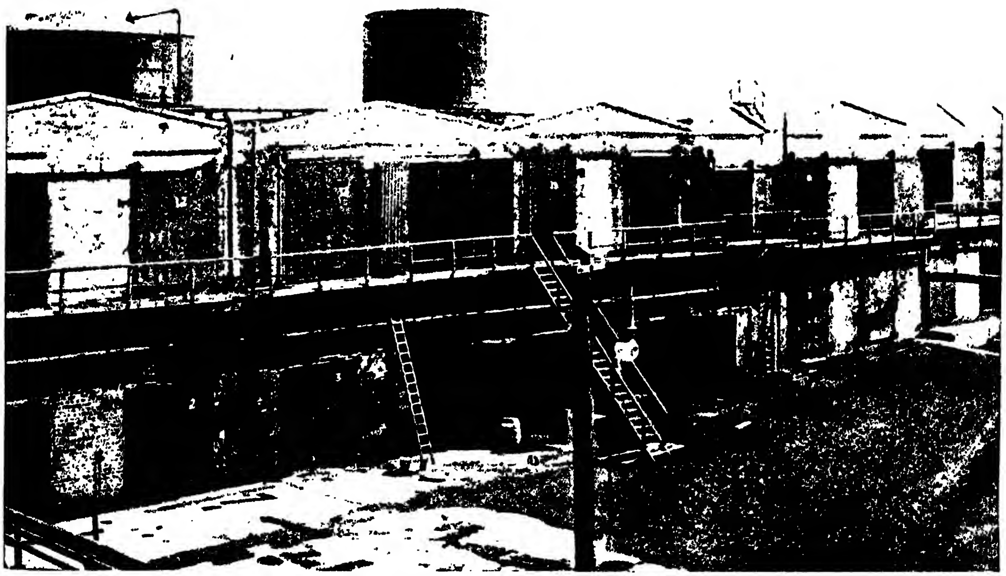
Perhaps all the rubber shares in whi there was so exciting a boom a few years ag have already lost a great deal of their valu For it is reported that M. Ostromisl sky, the young and brilliant professor chemistry at the Imperial Technical Scho of Moscow, has solved the problem synthesised rubber. In studying the pro perties of benzol, it is said, he found substance with a structure closely re sembling that of rubber. Then, acting o this discovery, he has employed ultra-viol rays in creating a perfect substitute for th natural product. The elasticity and r silience of the chemical substance are sai to be identical with tho of natural rubber, an the present price of th new material is a littl under 1s. 4d. a poun Para rubber, on th other hand, costs abo 4s. 10d. a pound. Cou Tatischeff, the head the United Bank and the Bogatir Rubber Com pany, has acquired th rights in Professor Ostro mislensky's discovery.

This does not mea that Russia is likely t control a new rubb industry. The matt will resolve itself into battle of wits betwe the industrial chemist of the civilised nation It will be remembere that an English chemist Sir William Perkins, wa the first man of science to create a dy out of coal tar, when he was trying t make a synthesised quinine. The profi of his magnificent pioneer work was, how ever, largely lost to our country owing to th divorce between our science and our in dustries. It was Germany, with her arm of industrial chemists, that chiefly benefite by the scientific achievement of Sir Willia Perkins, who was only eighteen years of ag when he produced the new colour of mauve

His success in 1857 excited a whirlwind o competitive enthusiasm. Everybody wh could devise a new oxydising agent at onc tried it on some coal-tar preparation, an obtained a new dye-stuff, and forthwit patented his process. Chief among th new dyes was magenta, which became th



RETORTS FOR THE PRODUCTION OF CRUDE OIL AND AMMONIA FROM SHALE



SWEATING-STOVES FOR THE PURIFICATION OF PARAFFIN WAX AT PUMPHERSTON SHALE OIL WORKS

storm-centre of a struggle between rival chemists. In France a great monopoly arose, and then men behind it tried to bring England and Germany under their heel. This excited a feverish activity on the part of English and German chemists. They had to find the secret composition of the new dye before they could attempt to reconstruct it by a better method. In 1878 the secret was discovered, partly by work done in England in 1862, but mainly by the labours of two great German chemists. It was not, however, till 1893 that Jennings assisted Professor Emil Fischer in filling all the experimental gaps in the science of the new dyes.

In the meantime, an enlightened and progressive company of German manufacturers had backed the chemists who were fighting the French monopoly, and they were rewarded by a finer monopoly than that which they had helped to destroy. Instead of the old coal-tar dyes, that were few in number, impurely distilled, and very apt to fade, the German company obtained an extraordinary, long series of pure and fast colours of exquisite gradations, by means of which they now practically control all dyeing industries. The annual value of the coal-tar dyes exported from Germany is about £8,000,000. The foundation of this huge industry was laid in England, but it decayed because our manufacturers did not recognise the value of the synthetic chemist, and would not employ him on long investigations.

PROFESSOR EMIL FISCHER, OF BERLIN

A few years ago there were not many great men of science who took the trouble to patent their discoveries. Even Lord Kelvin was regarded with a certain disrespect because he made a large personal profit out of his inventions, instead of freely giving his ideas to the world. But the fact is that many of our leaders of knowledge are disgusted with the want of interest and the lack of enterprise shown by our manufacturers. If they publish their ideas instead of patenting them, they merely help to increase the resources of other great nations, and of Germany in particular, whose business men have received a technical training which makes them extremely appreciative of any new idea in science that has a promise of commercial possibilities.

In pure science the British race is, on the whole, the first in the world. But in applied science we are behind several other nations. So our creative minds are growing weary of publishing their achievements and allowing them to become a source of profit to the intelligent stranger. Perhaps it is somewhat of a lapse from the standard of high and disinterested passion for knowledge which distinguished our men of science of the older generation for many of the most famous of our modern university professors to draw up patents of their newest discoveries. Yet the fault does not lie with them, but with our manufacturers, who are unable to see the value of an idea until it has been actually converted into money.

If Professor Lippman is correct in his views, the French captain of industry is scarcely more alive to the value of science than some of our manufacturers. Some time ago Professor Lippman worked out a wonderful process of colour photography. In order to get his countrymen to take up and develop the new method, the professor refrained from patenting his principal idea. The result was, he said, that nobody took any interest in it. "If you wish nowadays to give your discoveries to the world," he remarks, rather bitterly, "you must patent them." German men of science of the highest class—such as Emil Fischer, of Berlin, the greatest living master of organic chemistry, and Dr. Wilhelm Ostwald, of Leipsic, also famous as a chemist—patent every useful discovery of importance that they make. It may be that this is done partly from patriotic feeling, and with a view to preserving the supreme position which their country has won in chemistry. Some of the ablest of our own chemists are not so eager to patent their ideas, or to keep secret the composition of some new substance

CHEMICAL WEALTH LATENT IN COAL

NAPHTHALENE, A BY-PRODUCT OF COAL TAR, EMPLOYED IN MAKING SYNTHETIC INDIGO

SULPHATE OF AMMONIA, THE VALUABLE FERTILISER. A BY-PRODUCT OF COAL

that they have created. But as things now stand, it would not be bad for our country if they followed the example of the best minds of Germany. It might enable us in course of time to recover some of the ground we have lost by negligence and want of imagination during the last thirty years.

Yet, when all is said, it is a degradation for a creative chemist to work with one eye on pure scientific fame, and the other on the money-making possibilities of his ideas. Marcellin Berthelot, the man who, by continuing and expanding the work of Michel Eugène Chevreul, the father of modern French chemistry, founded synthetic chemistry, never in all his career turned one of all his long roll of brilliant discoveries to his own profit. "A man of science worthy of the name consecrates a disinterested life to the grand work of our age—to the improvement of the lot of all mankind, from the rich and the happy to the lowly and poor and suffering," said Berthelot in his old age. He was addressing all the chief functionaries of State assembled in Paris, together with representatives from a hundred and more of the chief learned and scientific societies of the civilised world. They had all come to honour the fifty years' work of Marcellin Berthelot, the creator of creative chemistry.

A SKEIN OF ARTIFICIAL SILK

Berthelot never had time to make money. One of his first exploits was to break up glycerine, and then study its combinations. This he did in 1854, and with a rapidity that is still a marvel he followed it up with a crowd of discoveries. Alcohol was built up from its elements; and then from a gas distilled from wood and coal Berthelot obtained the formic acid that used only to be produced by an ant. Experiments with artificial fats and sugars followed, and in the short space of five years Berthelot created the new science of synthetic chemistry. His master-work, "Organic Chemistry Founded on Synthesis," appeared in 1860—a year after Darwin's "Origin of Species," and a year before Pasteur's work on microbes. It is also to Berthelot that we owe the synthesis of acetylene, now so common as an illuminating gas. This was the point of departure for some marvellous creations. Condensed, simply by heating acetylene became benzine, the base of innumerable compounds; on adding more hydrogen, the new compound became ethylene, and ethylene with water gave the alcohol of our whiskies and wines.

When Berthelot began his work, only the acid of vinegar had been synthesised in 1845, and another natural product had been made by a chemist in 1828. These discoveries, however, had not been followed up. Most men of science still thought it impossible for man to compete with Nature. It was Berthelot who clearly showed that the creative power of the chemist was, as he said, "more powerful, more varied, than Nature itself." For instance, some twenty various fats can be obtained from natural products, but the modern chemist can, if necessary, create from these millions of others, the principal properties of which he can state in advance of his actual work of creation. Towards the end of his noble and laborious life, Berthelot prophesied that mankind would be fed by the chemist, who would bring our food no longer from the fields but from the laboratory.

Extravagant as the idea may seem, it was put forth by the great Frenchman after one of those remarkable experiments of his, showing clearly the enormous power that the chemist has in agriculture. It was Berthelot who discovered that the nitrates needed for building plants into food can be manufactured in various ways. He was the first to show the part played by microbes in obtaining nitrogen from the air. Then he sent currents of electricity through the earth that increased the absorption of atmospheric nitrogen. And at last he manufactured nitrates from the air by electricity, and thus prevented the universal famine in bread which Sir William Crookes prophesied would menace the human race.

It is doubtful if any selfish man of science has ever done half the good for mankind that Berthelot and Pasteur and Faraday performed without any reward. Berthelot's

early discoveries were the foundation of all the coal-tar dye industries, and the manufacture of the new medicines obtained from coal tar. As we have seen, the production of artificial nitrate, which will save the overgrown population of the world from starvation, was also his work. Following an idea of the great French chemist, a German man of science has succeeded in synthesising all the sugars; and the time may not be distant when artificial sugar will compete in the market with that which is fabricated naturally by plants by means of the sunlight and the soil.

It is, indeed, difficult to foresee the limits of the power of the synthetic chemist. He has armed mankind with the mighty explosives by which earth and rock are blown away at Panama, so that ships may sail through Central America, from the Atlantic to the Pacific Ocean. And the farmer is told that he can now plough with dynamite far more cheaply than with the best of modern machinery. Moreover, some French men of science are inclined to think that they will completely revolutionise the production of power, by means of a really explosive type of engine, in which the dreams of the old experimenters, with gunpowder engines, will be safely realised. When Berthelot took up the study of explosives, the old black powder was still in universal use. The courageous little Frenchman did not mind risking his life in the search after knowledge; and the result was that he succeeded in measuring the rate of all explosions, and in showing that they always occurred in the form of a wave. Then he built up his new compounds, and laid the foundation of vast industries that have made railway construction and mining and other arts of peace easier to pursue.

Far more important than any explosive, however, is the new strange force by means of which the creative chemist of our days performs many of his wonders. This new force in chemistry is the "catalyser," a marvellous thing with which few members of the general public seem to be acquainted. With the discovery of the action of various kinds of catalysers, the modern chemist has apparently penetrated into the ultimate secret of natural forces.

It must be admitted that the ordinary procedure by means of which a chemist imitates the processes of Nature is very crude. He has to use great heat and violent methods to produce the substances that plants and animals manufacture in a gentle and natural way. For a long time he was quite at a loss to discover how a microbe could transform one form of matter into another without the powerful apparatus of a chemical laboratory. But at last he found out that certain substances in extraordinarily small quantities, have the power of provoking great changes in large mixtures of various kinds. For instance, the ten-thousand-millionth part of a thimbleful of blue vitriol will bring about a reaction between certain substances. Finely divided platinum is a catalyser with a large range of action. Merely one-16,000th of an ounce of it will reduce a pint of the bleaching mixture of hydrogen peroxide to water and oxygen. If, on the other hand, the platinum is mixed with hydrogen and oxygen, it will turn these two gases into water without any heat.

WINDING AND SKEINING ARTIFICIAL SILK FROM WOOD PULP IN A LARGE EUROPEAN FACTORY

And the marvellous thing is that, when the water is formed, the platinum is ready to produce over and over again the same effect. It is not worn away or diminished in power by the strong and large reactions it produces in mixtures of other elements. Suppose, by throwing a few handfuls of some new substance on the Isle of Wight, the

whole of the island could be changed into a liquid mass? Well, that would be on a large scale a catalytic reaction such as chemists are now able to produce on certain compounds with a marvellously small amount of the catalysing substance. A catalyser that can set loose the store of electric energy in a pebble, and light London

EUGENE CHEVREUL BEING HONOURED BY FRANCE ON HIS HUNDREDTH BIRTHDAY

with it, is not impossible of discovery. Indeed, men of science are now attempting to find such a catalyser.

It will thus be seen that chemists are in a way to obtain control over an extraordinary force in natural processes. They have found in the bodies of plants and animals substances that work in somewhat the same way as platinum does. Merely by their presence, these substances convert one kind of compound into another. For instance, there is something in yeast which has the power to transform 200,000 times its weight of sugar into another substance. Again, rennet will change 400,000 times its weight of soluble casein. All the kinks and corners of the bodies of plants and animals have these efficient little chemical substances, which, at the right time and the right place, exert their catalytic power on the juices of the organisms.

It is not beyond the new creative power of man to manufacture some of these natural catalysers in his laboratory. For example, an extract from the suprarenal glands has an astonishing power to augment the blood-

pressure. Out of this extract there was isolated a definite substance named adrenalin. Chemists then carefully analysed this natural product, and ascertained exactly of what elements it was composed. When they had succeeded in breaking it up, they began to put it together again out of various things found in coal tar. At the present day synthetic adrenalin is cheaply manufactured into an article of commerce, and its action on the blood-pressure is identical with that of the substance from the natural glands. By means of it a modern surgeon now controls the blood-pressure of a patient during an operation. So one of the most mysterious functions of the body is often performed by an extract from coal tar. In both the organic and the inorganic world the creative chemist has found a very great number of catalysing agents, and with some of them he has begun to revolutionise several very important industries. The manufacture of sulphuric acid, for instance, need not now be carried on in huge leaden chambers. A little platinum does most of the work.

SIR WILLIAM CROOKES IN HIS LABORATORY

Getting nearer to the mystery of life, the chemist has discovered that there are anti-catalysers, which prevent the action of the real catalysers. It seems extraordinary to talk about poisoning a metal, but that is practically what an anti-catalyser does. A little prussic acid, for instance, will take away the powers of platinum, and prevent it from doing its work. There is an interesting similarity between this occurrence and the poisoning of the living cell by the same deadly acid. On the other hand, the living body often manufactures a small quantity of some poison by means of which it retards, when necessary, the action of its natural catalyser. There are no poisons, it has been well said, but merely poisonous effects. But sometimes the control is effected, by making two catalysers which only act when they come together. So much progress has been made in the study of catalytic effects that all the problems relating to the chemistry of life have become very complicated. It will require the work of generations of chemists to analyse into their elements all the catalytic substances found in living tissues; and very likely a still longer period of time will pass before these substances have been manufactured in a laboratory. On the other hand, Professor Fischer, of Berlin, has already succeeded in manufacturing artificially some of the proteids of protoplasm, which is the physical basis of life. And it is known that all the main reactions in the living processes of digestion and respiration, the conversion of food into tissue, and the elimination of waste products, are governed by catalytic influences.

Yet few modern chemists are now bold enough to prophesy, with Berthelot, that life itself will one day be found in the tube of the man of science. It is true that the chemist can now create more substances than the life-force can manufacture in plant and animal. It is true also that he has reason to believe that what we call life is nothing but a complex product of innumerable chemical reactions in the living substance of protoplasm. The idea of life as a mere mechanism is completely exploded. On the other hand, the modern chemist is filled with awe at the infinite adaptability and delicate and subtle strength of the lowliest of living things. He cannot deny the existence of a spiritual entity abiding within the body and directing its activities, without adding to the sum of actual material energies. And if, after all, man at last succeeds in unveiling the mystery of the material garment of the spirit of life, it will surely be by reason of the soul within him, with its high, pure, disinterested passion for knowledge.

THE OLD CONVENT GARDEN THAT SERVES MILLIONS OF PEOPLE DAILY WITH VEGETABLES

AN EARLY MORNING SCENE IN COVENT GARDEN MARKET ONCE THE REAL GARDEN OF THE CONVENT OF WESTMINSTER

THE MARKET GARDEN

The Precarious but Growing Industry of Producing Fruit and Flowers for the Table

THE PROBLEM OF REACHING THE BUYER

THERE is not much intrinsic romance in a cauliflower or a tomato, but quite unsuspected talent may have gone to the production of either. There is money in both, but brain is required to bring cauliflower or tomato to market in due season. The man who grows the cauliflower may be cultivating strawberries for Mayfair, and fruit for the poor man's jam and puddings. The man who produces the tomato at a rate cheap enough to bring it within the worker's reach may be also a purveyor of rare exotics for the adornment of luxurious homes of the wealthy. Market gardening in the vicinity of London and other great centres of population has become a highly organised industry, employing enormous capital and a great army of men. The old market gardener is dead, and his methods are buried. The successful new market gardener is a genuine Nature-student as well as a business man.

The personnel of the market gardening industry is distinctly interesting. Among the growers of our daily commodities we find men who have had charge of some of the finest private establishments in the country, men who, having grown pines at a guinea apiece for a British Prime Minister, cheerfully turn out tomatoes at twopence per pound for that puissant statesman's humble contemporaries in the street. Some new discovery in botany is mentioned at the British Association, the result of investigations by a man known to the savants, but a stranger to the outside world. That self-effacing hero of research, if tracked down to his laboratory, will be found, it may be, in association with the statesman's botanical coadjutor; his head in the high heaven of his science, his feet in honest clogs in which he wades through the clinging soil of glasshouses where he means to make forty tons of tomatoes grow where thirty tons grew before. One of the twain graduated at Kew, and worked with men of world-wide fame at a university botanical laboratory; the other has an equally enviable record in other paths, and both have held important tutorial appointments in colleges where the art and mystery of growing fruits and flowers and vegetables are taught. Yet here they are, their reputations in the academic subordinated to new reputations in the utilitarian. Many men of education and means have entered the market gardening world, and more are following. The work is hazardous, it is not without trial and vexation and loss, but neither is it without its fascinations and its rich reward for the man with brain, originality, and industry.

"Why, you have no farmers here—you are all market gardeners!" said an American visitor to the Home Counties the other year. But there is a recognisable dividing line. The nurseryman propagates and sells shrubs; the market gardener produces flowers, fruits, and vegetables for market. He may occasionally grow other things for the benefit of the soil, but that is in the nature of a gift crop. He may confine himself either to outdoor or indoor work, or may combine both. It may make for clearness to consider the subject under two separate heads, and it will be understood, of course, that the figures given are only approximate, these being determined by local conditions as to labour, distance from a town, trade fluctuations, and so forth. It will be of advantage, perhaps, to reason from the infinitesimal. Successful market gardeners begin as a rule in a small way, and grow with experience. We take, then, the man with quite modest capital, and imagine his opening up a little enterprise in the Home Counties.

He must have an acre of land and six to eight houses—almost inevitably eight—of

100 ft. each in length. There are two ways in which he can proceed. He may rent or hire. Should he rent, he will be charged, say, £5 per 100 ft. of glass, which price includes the hire of the acre of land. That means £40 a year rent—rather an extravagant sum. The better plan is to buy the land—probably at a cost of £100 per acre—and build. Now, the price of the houses may vary considerably with the time of the year. That season should be chosen in which the builder has least on hand. At such a time the eight houses may be built for £500, so that houses and land are the property of the market gardener for the equivalent of fifteen years' rent. The price paid includes the cost of boiler and hot-water pipes. There remains an expenditure of £20 on pots, and another £20 on tools, and between £40 and £50 for the first year's fuel bill. Coal or coke averages out at the same figure. Anthracite coal, though dearer, of course, than coke, lasts longer and gives less labour.

Now, the problem is to make each foot of these eight 100 ft. houses return 10s. per annum. That is the figure at which the gardener aims. He will not often attain it, but that is his commercial ideal. He has three lines of appeal. First, there is the hearty appetite of the man in the street for tomatoes of the finest kind, sold as cheap as gooseberries. To meet that demand the gardener must make a single tomato-seed yield him fully twelve pounds of tomatoes. He stocks a whole house with a shilling's worth of good tomato-seed, so the outlay at the outset is not alarming. He plants his seeds in January, and, not being a gambler, declines to force too severely, but is content to wait until June for his tomatoes, when he may start at 4½d. per lb., and gradually drop to 2d. per lb.—these prices being obtainable only for the best quality.

Cucumbers may be the next seeds set after tomatoes; but though the seeds are not put in until February, the cucumbers will be ready for cutting in May. It is possible to obtain the same result in three weeks, but not on a fuel bill of £50 per year. Growers on a big scale, who can afford the risk which attends hard firing, can set their seed at the end of March, and get their first cucumbers by the middle of April.

Then there is the luxurious palate of the wealthy, to which appeal can be made through the medium of forced strawberries. Forced strawberries are obtainable at Christmas time at 30s. per lb. wholesale price but they are not the product of the little man. The latter buys his runners, from which the plants are raised, during the summer, paying from 3s. to 8s. per thousand. Each runner is "layered"—pinned down to the soil of a pot to grow. It stands out in the open until about Christmas.

MUSHROOMS ON A HOTBED
Photograph, J. Carter & Co.

Frost does not hurt but improves the strawberry, provided that the plant is not previously too damp. To guard against this, the pots containing the plants are laid upon their sides, so that they shall not absorb too great a quantity of water. Brought into the houses in December, the strawberry plants, of which there will be some 16,000 in pots, are expected to yield from three ounces to four ounces per pot. The best of the fruit, when it is picked as it should be from March to the end of May, realises from 4s. down to 2s. per pound. Demand fluctuates; so do prices. A series of banquets or other public entertainments raises the price immediately; an exodus from town sends it down with a run; and anything which puts society into mourning is fatal to the trade. In one case successive sales represented a drop from 8s. 6d. to 3d. per pound, the first price being obtained on the Thursday

preceding an Easter; the second that returned for the Easter Saturday, when town was empty.

But carefully tabulated figures kept for the last ten years show that the trend is slowly downwards, owing to increasing competition. Ten years ago the price for best quality of strawberries throughout the March-May season averaged 2s. 7d. per pound. It has dropped little by little, until 2s. 4d. now represents the figure. Of course, the poorer grades, divided into seconds and thirds, are not included in these returns. It is to be understood that there never was a forced strawberry worth eating. The appeal is solely to the eye.

TENDING THE HOTBEDS IN A FORCING-HOUSE

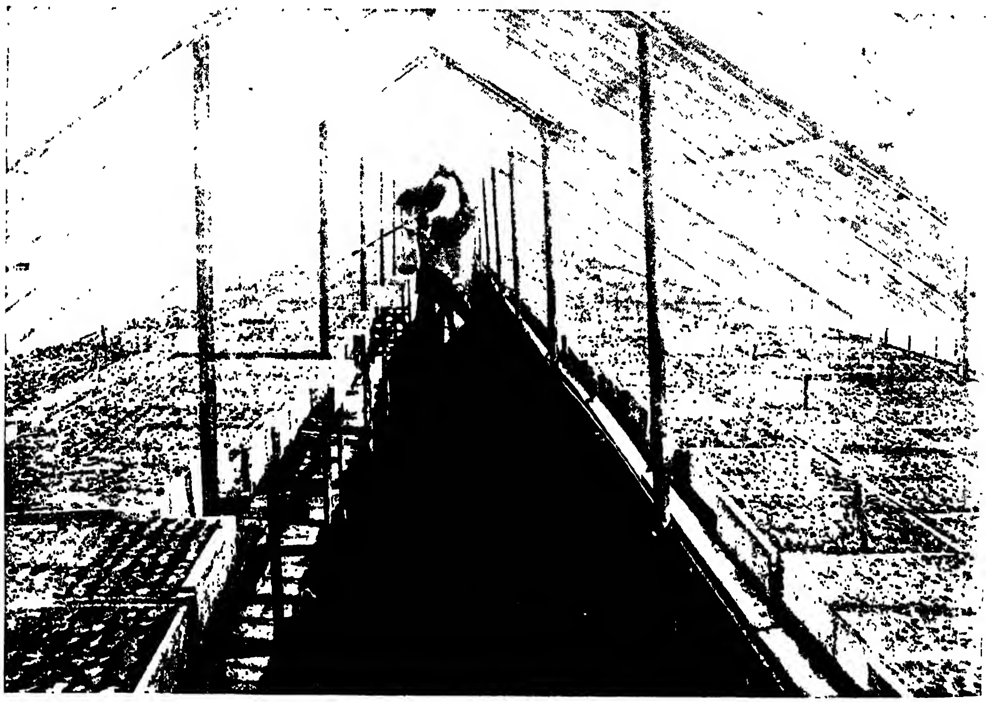
The indoor strawberry is a thing of beauty, large, delicate of scent, with a surface like satin, incomparably handsomer and cleaner than the outdoor fruit. But it can never be rendered sweet; nothing can replace the open air and sunshine. You look at a forced strawberry, then smother its crisping acidity with cream and sugar.

The third line of appeal is to the æsthetic sense of the public. The artistic housewife must bedeck her home with flowers, and it is the function of our market gardener to furnish supplies when frost has cut off all outdoor blooms. Therein lies one of the secrets of his calling's success. His greenhouses make him largely independent of minor climatic changes which are fatal to outdoor growths. A good house of glass, unheated, will keep out five degrees of frost; hence, with fire to supply the heat which the weather denies, the market gardener can reach the public with his wares both before and after the normal season. Therefore, in order that his houses may be productive when chill winter draws near, our man lays in a stock of chrysanthemum cuttings early in the summer, and plants these out in his open ground. He will get a good market variety for 15s. per thousand, and of these he will require some 16,000. Provided that the weather is seasonable, his sale for blooms may begin in the middle of October, and he is anxious to get his houses cleared as soon as possible after Christmas. Discretion is required in the choice of plants, so that by a range of successional varieties he gets his blooms not all at once, but in a steady supply. His earliest flowering sorts he places farthest from the centre of greatest heat, position of favour being allotted to those latest to bloom. With the arrival of Christmas the strawberry plants are brought in again; then follows the sowing of tomato-seed, and the whole cycle runs its course anew.

Provided that he himself is a good worker, the market gardener can run his eight

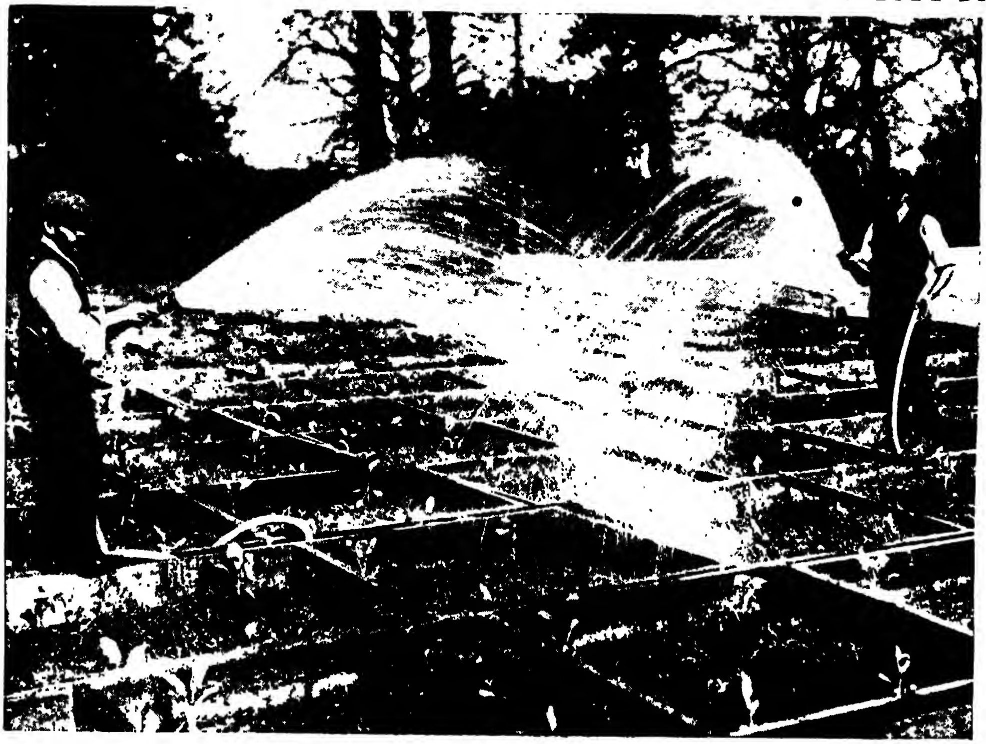
houses on these lines with the assistance of one man or a strong youth. Even in the London area, where labour is necessarily dear, he should get the help that he requires for £50 a year; and with ordinary fortune there should be a margin of from £50 to £80 a year for the proprietor in his first year. This all seems small and petty, no doubt, but it is upon foundations such as these that some of the biggest of market gardens in the Home Counties have grown. With additional experience and profit new possibilities arise. Carnations, arum lilies, maidenhair and the more expensive ferns are added. Enormous numbers of bulbs are forced during the cold weather: one man alone disposes of the product of over a million bulbs in the course of the early winter, mainly tulips, daffodils, etc. This is a growth necessitating heavy firing, and the results are very speculative. He succeeds best who most closely follows the whims of fashion. The market gardener must appraise the value of his wares, not from their appearance in his house, but from the aspect they will present when employed as table decorations in artificial light. Fashion and demand are fickle, and the results are curious. There is a certain rose which flourishes under glass; London will not have it, yet it is extensively grown in the south. It goes to Yorkshire and Lancashire to form buttonholes for the artisans and textile workers. Take another example.

The market gardener must grow the size of goods required. Up to a year or two ago the salesmen demanded five tomatoes to the pound. That exactly suited a certain excellent strain. Today the tomatoes must be small enough to give six, or even seven, to the pound. That has meant the introduction of a new variety of tomato. But initiative is even more important than compliance with demand; and just one point under this head. The grower, as we have seen, expects, or hopes, to get a peck of twelve pounds of tomatoes from each of his plants. Now, quantity is not alone of importance; value is governed by the time at which the goods can be delivered. Everybody can put tomatoes on the market in July, by which time the price is down to 2s. or 2s. 6d. per peck. The high prices await the man who can have his tomatoes on sale in May. For a brief season at that time of the year 10s. per peck can be commanded. How, then, to get bulk early? Certain acute growers have introduced a variety which yields enormously at the outset. The ordinary tomato plant is fruitful enough if given time and allowed



WATERING YOUNG BEGONIA PLANTS IN A GREENHOUSE

THE SPEEDING UP OF VEGETABLE LIFE



WATERING THE YOUNG PLANTS IN THE FRAMES

COVERING THE GLASS "BELL" COVERS WITH MATTING TO GUARD AGAINST NIGHT FROSTS

to produce fruit in small trusses slowly all along its growing stem. This new tomato, however, throws its strength into the earliest truss, from which forty, fifty, and even sixty tomatoes can be gathered. The plant is so treated that that truss shall be safely ripened. From that one cluster from seven to nine pounds of fruit are gathered, and after that the plant may run on and produce tomatoes in profusion for the time of smaller prices. The whole industry lends itself to business treatment, whether it be that of the man who grows luscious grapes by the ton, peaches and nectarines by the cartload, or melons which come in upon a date when they will fetch over half-a-sovereign apiece.

The outdoor man is pledged to a smaller expenditure of money, but his risks are, of course, infinitely greater. The man with houses starts with water assured; the outdoor man has none save that which the clouds bestow, while he has the fear of frost or storm ever before his eyes. Having decided to chance the risks, he may begin with five acres of land, which he rents at, say, £2 per acre. He does not embark upon an extensive outlay for implements. He can get his land ploughed by steam-plough for 15s. an acre, but a motor-plough, which draws four ploughs for as many furrows simultaneously does the work at half the price, and does it admirably. For the fertilisation of the soil he may require from 20 to 40 tons of stable manure per acre, or, where artificial fertilisers are used, about half a ton per acre. The first costs, including cartage, 5s. per ton; the artificial, from £6 to £9 per ton. Certain minor accounts under the same heading have also to be taken into consideration.

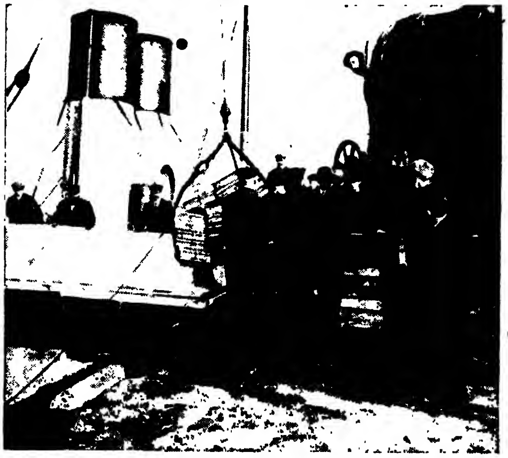
There are many combinations of crops—the market needs them all, but we may imagine an example. This man sows onions in February, potatoes in March: then radishes, sprouts, various cabbages, cauliflowers, lettuce, spinach, and the like follow, with scarlet runner beans, perhaps beet, and certainly strawberries when the latter are to be had at 3s. per thousand runners. Radishes, which are among the earliest crops, yield about 90,000 to the acre, and are sold at about 6d. per dozen bunches. Potatoes, of which 15 cwt. per acre of seed, at from £4 to £5 per ton, are required, return from 15 to 18 tons per acre, which are divided, for purpose of sale, into three grades, known as "ware,"

POTTING THE YOUNG PLANT IN PREPARATION FOR BEDDING OUT

FLOWERS FROM THE ISLES OF THE WEST

PICKING NARCISSI IN THE SCILLY ISLES AND BRINGING THEM TO THE PACKING-SHEDS

PACKING THE FLOWERS FOR DISPATCH TO THE BIG MARKETS OF GREAT BRITAIN



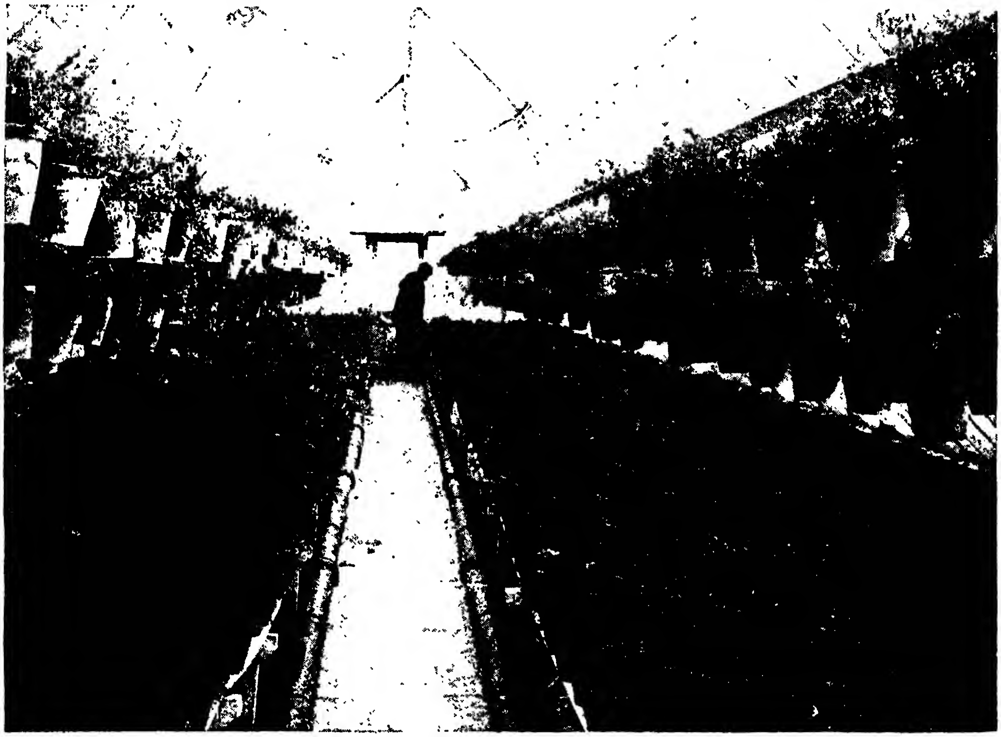
UNLOADING THE BOXES OF FLOWERS AT PENZANCE FOR TRANSMISSION BY RAIL

"middlings," and "chats." Of these the first realise from about £4 per ton, the second 30s. to £2, and the inferior a sovereign a ton. In accordance with the time of planting they may be dug in July or October. Prices vary greatly, and that of cauliflowers may be taken as an illustration. One and the same man, a keen scientific grower, has at one time made 2s. 6d. per "tally" (or sixty) cauliflowers, and at another time 12s. for the same quantity, when other greenstuff has happened to be short.

In certain favoured spots open-air tomatoes are a source of profit, but in a climate such as ours the crop is always a hazardous one; and as between this and strawberries, the latter are the more advocated. Those grown out of doors yield fruit in their second season; they are at their best during their third and fourth seasons, but continue to bear in their fifth year. As much as 800 pecks per acre have not infrequently been returned, but the average is between that figure and 400 pecks. The man who got 12s. wholesale for his cauliflowers once received 6s. 6d. per peck for his strawberries. He happened to have a patch ready when all the indoor strawberries were finished, and there was an important society function toward. But as the same man has sold magnificent fruit at a penny a pound, it will be seen that the sale of the strawberry is not exactly all profit.

Strawberry growing is becoming rather a serious problem. The Paxton, which was long the stand-by, favoured alike for flavour, colour, and size, is said practically to have grown out of cultivation; the Royal Sovereign, its successor, is reported to be rapidly following suit. There is a cry for a new strawberry; and one highly experienced grower declares that at the present time there is not a good strawberry on the market; good, that is, from the grower's point of view—a strawberry which, while generous in yield, is also of good flavour. To what extent growers have contributed to this state of affairs, by sacrificing every other consideration to size, they best can tell. Certain it is that the strawberries of finest flavour today are those which do not appear among the "firsts" or highest grade in the markets.

Other fruits which engage the attention of the outdoor man are raspberries, which can be bought at from 10s. to £1 per

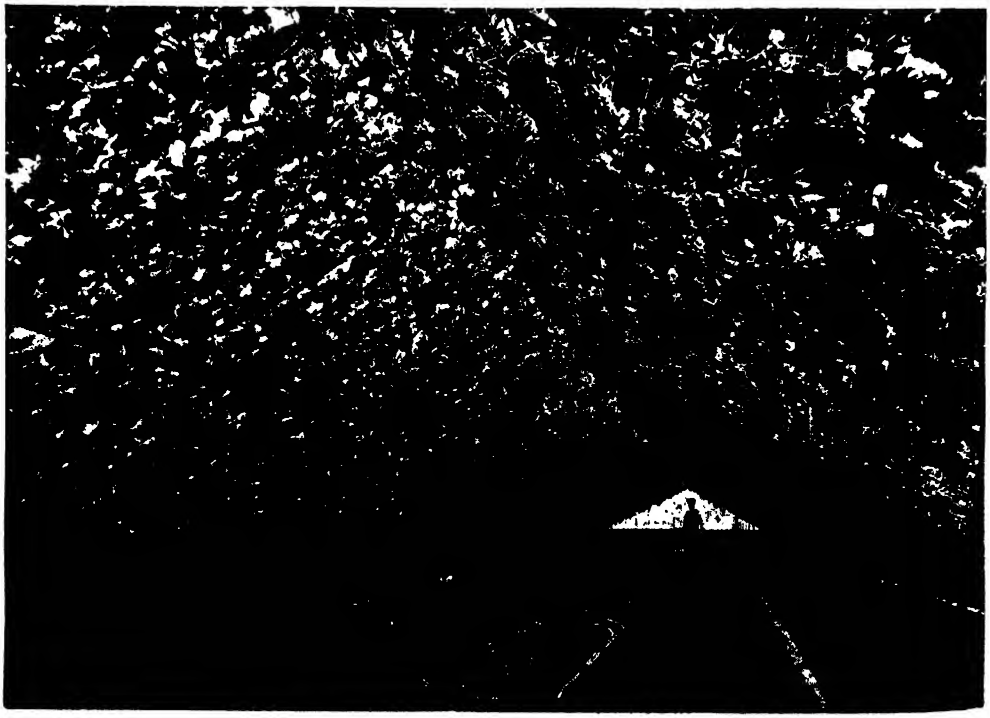


A FERN NURSERY FOR THE LONDON MARKET

WHERE CHOICE FLOWERS COME AND GO

THE FLOWER MARKET AT COVENT GARDEN, WHERE THE LOVELIEST FLOWERS ARE SWIFTLY COLLECTED AND DISPERSED

A VEGETABLE OF MODERN TIMES—TOMATO CULTURE IN A KENTISH GREENHOUSE



A FRUIT OF GREAT ANTIQUITY—BUNCHES OF GRAPES IN A VINEYARD

FINE PRODUCTS OF A VEGETABLE GARDEN

A FIELD CRAMMED WITH EARLY DRUMHEAD CABBAGES

A REMARKABLE YIELD OF GREAT WHITE BELGIAN CARROTS
From photographs taken by Messrs. Sutton & Sons

thousand bushes; currants, black or red, at 10s. per thousand; gooseberries at the same price; and apples, pears, plums, or cherries at from 6d. to 1s. each for either standard, half-standard, or bush. Prices for currants and gooseberries range between 1s. to 3s. per peck; raspberries, which average between one to two tons per acre, run from £14 per ton to four times that price. In 1911 the average minimum was £20, the average maximum £40, per ton. But these, like strawberries, are very perishable. Their growth cannot be retarded; and, should they ripen upon a bad market day or during the week-end, they may be unsaleable by the time they reach the depot.

Peas and runner beans have their pecuniary attractions, but the last-mentioned are peculiarly susceptible to frost. There is also the question of providing sticks, and the labour of fixing them. This amounts to about £10 per year, and must be considered an annual charge, inasmuch as one year's supply of sticks is not as a rule available for the succeeding season.

Only a few heads of the market gardener's craft have here been considered, and the matter of rotation of crops with a view to restoring nutriment to the land does not come within the scope of the present chapter. Sufficient has been said, however, to indicate the lines upon which rests the vast industry that provides our cities with their daily supply of vegetables.

This industry, as has been indicated, is very much larger than the man in the city street imagines. It will be larger still. With every year we realise more and more the importance of fresh vegetables and fruit in our diet, and the demand for both is growing. There are no better gardeners in the world than those of our Home Counties, of Sussex, of the Evesham Valley, of the Fylde of Lancashire, of certain parts of Scotland, and many other centres which will readily come to memory. But the great weakness is in the matter of distribution. There are many links missing between growers and consumers. On the one hand, there is short-sighted pursuit of an ancient idea; on the other, lethargic indifference to obvious possibilities. For generations it has been the habit of growers of fruit and vegetables and flowers to send their produce to Covent Garden, to the Borough Market, to Spitalfields, or Stratford, but mainly, of course, to the first-named.

GATHERING THE FRUIT FROM THE APPLE-TREES IN A KENTISH ORCHARD

SCENES FROM STRAWBERRY LAND

SPREADING STRAW EARLY IN THE SEASON TO KEEP THE FRUIT CLEAN FROM THE SOIL

THE JUNE STRAWBERRY-PICKING IN KENT

LOADING THE FRUIT FOR COVENT GARDEN

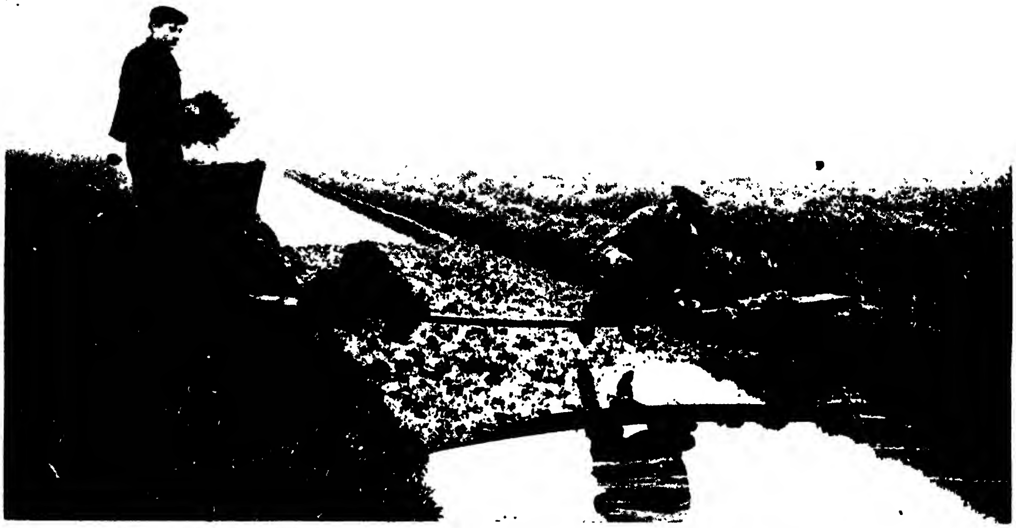
It might almost be that money for garden produce is minted at Covent Garden. A sovereign seems to possess no value if drawn from a purchaser in the vicinity of the place where the crop is grown, but all seems well when the goods have been sent by expensive transit methods to London, when market dues have been paid, when salesmen's commissions have been met, and a price returned to the grower which there is no common means of checking. It is a vicious system, and its effects are curious. In the heart of strawberry-land the shopkeeper, as often as not, obtains his strawberries not from the man in the village or little town, but from a distant middleman who has ordered from Covent Garden fruit which has been carried from Kent up to town, and then brought back to the place where it was grown. There is an absurd waste of money and labour here. The grower's answer is that it does not pay to sell in small quantities upon demand of uncertain dimensions. But fruit should not have to travel round a town by way of London and back again.

The market gardener receives 2d. to 2½d. per pound for tomatoes for which the ultimate purchaser will pay 6d. or 8d. Either the grower should receive 100 per cent. more, or the consumer should pay 100 per cent. less. That can never happen so long as the present system prevails. As matters now stand, the outdoor man, sending in bulk, must pay the railway company 6s. per ton for a railway journey of less than twenty miles, or, chartering a horse and van, pay the not excessive sum of 16s. per horse required for his load. The advantage lies with the van, especially in the case of perishable and delicate fruit and flowers, for, trusting to the railway, there are some half-dozen different handlings of the produce—into the van, from the van to the porter's barrow, from the barrow into the train, from the train to the porter's barrow, and then into the London van. Sent by road, the goods enter the van at the market garden, and are unloaded at the London stall where they are to be sold. Many market gardeners keep their own vans, of course, and not a few run traction or motor engines—the latter being the coming method of transit for the whole trade. The small man with the eight houses, however, must trust to a carrier, and many carriers live by conveying these products to town at astonishingly cheap rates—some 1½d. or 2d. per package of 12 lb.

PACKING APPLES THAT HAVE BEEN GRADED

But by whatever means the goods are carried, they are sold by market salesmen, neither under the eye of their producer nor that of any friendly overseer. The salesman obtains as much as he can get, but in spite of market lists the market gardening world rings with complaints as to prices reported for sales. The proprietors of the markets realise enormous profits, a toll upon every package unloaded from a van, and the salesmen get their 7½ to 10 per cent. on all

A FLOATING GARDEN OF WATERCRESS



PREPARING A BED FOR THE CULTIVATION OF WATERCRESS

PLUCKING AND BUNCHING WATERCRESS FOR THE MARKET

PRESSING DOWN THE ROOTS THAT HAVE BEEN DAMAGED IN THE PLUCKING

sales, without a farthing's worth of risk. It sometimes happens that, owing to a freakish market, such precious goods as a load of strawberries or a huge consignment of arum lilies remain unsold, and the unfortunate grower has to pay for the labour of gathering, packing, carriage up, and perhaps carriage back again if the goods should be returned to him. The bigger men, of course, have their own salesmen, but this is impossible to growers of slender resources. But with half an hour's conference they might by combination appoint their own salesman. If he could not get a stall—and strange tales of preferential treatment and "rings" are told—then some genius might arise who would strike a blow for sanity and invent a new way of reaching the consumer without prodigious journeys and the payment of inequitable tolls and commissions.

It is no easy thing to establish a new market. The late Baroness Burdett-Coutts tried and made a costly failure with Columbia Market, one of the finest structures of the kind ever erected. But a way out from the present anomalous position has to be found. As matters now stand, we have the markets glutted with fruit or vegetables while the poor are languishing for both, and unable to obtain either at a reasonable price; and yet the man who has grown this desirable food receives the melancholy market tidings "No sale," or something equally dispiriting.

With an intelligent attempt at combination the market gardeners of England would enormously enhance their takings without raising the price of foodstuffs to the public. Plums flood the market for a few weeks, fetch absurdly low *wholesale* prices, and then not a plum is available. But Australia and New Zealand can send us their plums, their pears, their apples, and other perishable fruits, half way round the world, to reach us in perfect condition, and to realise, the plums 5d. and 6d. each, the apples 6d. and 8d. per pound. They know the value and profit of cold storage; our market gardeners do not. There is money enough in the English market gardening trade to establish large central cold storage depots, but none such exist, and the result is that all our fruit crowds into the market at one time, and is gone, like a whiff of ignited gun-cotton, at garbage prices.

Our market gardeners have learned pretty well all there is to know about cultivating

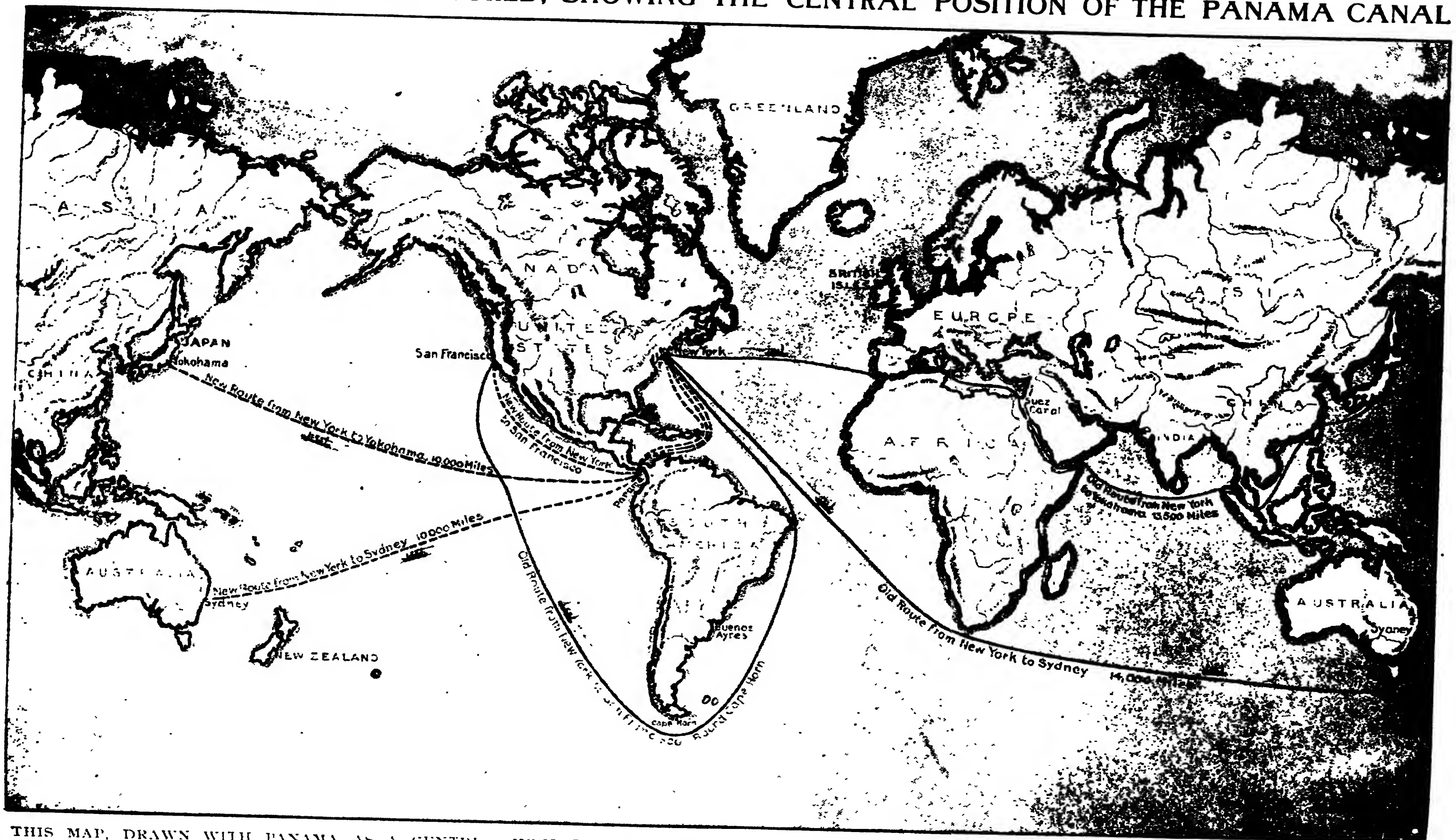
REMOVING POTATOES FROM THE "CLAMP" IN WHICH THEY HAVE BEEN PRESERVED

LOADING TRUCKS WITH HAMPERS OF NEW POTATOES GROWN IN THE MIDLANDS

heir land, but they have much to learn in he way of cultivating direct custom with heir public. The middleman and the huge entral depot will never be eliminated, but there should be a multiplication of depots, and the middlemen should be of the growers' own choosing. He should be their servant, not the servant or ally of the commission agents who now handle supplies. There should be combination for purchase of supplies, for transport, for sale and distribution. The receipts of market commission salesmen would be diminished, but those of the men who take all the risks and supply the brains, the labour, and the capital of the industry would be vastly increased; while, with fewer barriers between the market garden and the dinner-table, the consumer would get what he wants, when he wants it, and at a price he is able to pay.

SORTING AND WEIGHING A TRUCK-LOAD OF POTATOES AT KING'S CROSS MARKET

A MERCATOR MAP OF THE WORLD, SHOWING THE CENTRAL POSITION OF THE PANAMA CANAL



THIS MAP, DRAWN WITH PANAMA AS A CENTRE, SUGGESTS THE COMMERCIAL FACILITIES AFFORDED BY THE CANAL TO THE UNITED STATES

SHORTENED TRADE ROUTES

The Effects of the Coming Panama Canal from a Commercial Point of View

THE GREAT RELATIVE GAIN BY AMERICA

A GLANCE at a Mercator map of the world—or, better, a survey of the world's land and sea spaces as shown more accurately on the too much neglected "globe" will show that, when man learned to navigate the great waters, the world presented two small but very effective land barriers to the sea-voyager. We see the great mainlands of Asia and Africa linked by the tiny Isthmus of Suez, and we see the two tapering Americas made one by the narrow neck of Panama. It was as though Nature left man two problems to solve in order to remind him of the nature and magnitude of the mighty works she herself accomplishes so easily.

The first named of the two problems was attacked thousands of years ago by the ancient Egyptians. True it is that they never attempted to make a direct cut through the neck of land, but the waters of the Nile formed a natural base from which to make a connection between the Mediterranean and the Red Sea. The first of such canals known is that of the time of Seti I. (1380 B.C.), and it is pictured on the walls of the Temple of Karnak. Other and more ambitious attempts—some of them costing tens of thousands of lives—followed; and in 1861 French engineers were actually able to utilise part of the work of the ancients in constructing the fresh-water canal from Cairo to the Red Sea.

But for the Turks there might have been a Suez Canal proper many centuries ago. The design of a direct cut from the Mediterranean was conceived by the Venetians, but their negotiations with Egypt ended with the conquest of the land of the Pharaohs by the Turks, when, of course, engineering and commercial enterprise alike came to an end. No more was done until more than half-way through the nineteenth century, although the Great Napoleon was fascinated by the subject in 1798, and caused a survey to be made—unfortunately by an engineer who was deceived as to the respective levels of the Mediterranean and the Red Sea.

As late as 1823 the only passenger route to India was via the Cape of Good Hope. An Indian merchant could not obtain communication with his customer or agent in the East under about six months. Less than a century ago trade with India was thus a matter of extreme difficulty. In 1840 an overland route to India was devised, which, although very expensive and cumbersome, was a great assistance to trade and communication. A ship sailed to Alexandria, and from thence her mails and passengers went overland to Suez. At Suez they were picked up by another vessel, and taken to Bombay or Calcutta via Aden. Much time was thus saved and much trade thus created, but the process was a clumsy one.

Suez Canal projects were revived in 1846, when French engineers reported in favour of a route via Cairo. The origin of these projects, which led directly to the great work of De Lesseps at Suez and Panama, is of much interest. It began with the Comte de Saint-Simon, the French Socialist and dreamer of great dreams, whose scheme for the regeneration of the world included a Panama Canal and a canal connecting Madrid with the sea. Prosper Enfantin, one of his chief disciples, organised the society which made the Suez surveys of 1846, and Ferdinand de Lesseps gained his idea from the Saint-Simonists.

It is unnecessary to trace the history of the Suez Canal undertaking in detail, but it is of interest to observe that its progress was marked by a curious illustration of the worthlessness of cheap or forced labour.

At first forced labour was supplied to De Lesseps by Said Pasha. When this evil system was ended by political action, and the company compelled to dispense with it, greater attention was given to mechanical labour-saving appliances, and greater progress was made. The first capital was subscribed in 1858, construction commenced in 1859, and the formal opening took place in 1869. Thus, in 1912, this great highway is little more than forty years old.

In 1875 Lord Beaconsfield wisely bought for the British Imperial Government the Khedive's holding of Suez Canal stock—about one-half the capital of the industry—for only £4,000,000. The stock is now worth over £30,000,000, and yields £1,000,000 a year to the British Government, or 25 per cent. on Lord Beaconsfield's investment. It is a wonderful development, in view of the fact that, more than half way through the work, De Lesseps had to issue canal stock at a heavy discount in order to obtain more capital, and had even then to devise a lottery in connection with the discounted issue to attract applicants.

The World as an Estate Whose Development is Only Just Beginning

This first great emendation of the world's geography made an enormous difference to European trade with the Orient and with Australasia. Ships gained a straight course through to the lands of the Southern Cross, and the great markets of the Near East and Far East were developed as never before. It is necessary to remember the recent date of these developments to understand the commercial history of the world in the last generation, and to comprehend that *we are but just beginning to develop the world as an estate.*

Important as was the Suez Canal to Europe and the world at large, the work which is now proceeding so rapidly at Panama far transcends it in magnitude and effect upon commerce. It is as yet little realised what changes will be wrought in the world by the great Central American enterprise—the greatest engineering work the world has ever seen.

The industrial side of the Panama undertaking has been already dealt with under Industry, Chapter 16. It remains to consider this exceedingly important matter from the point of view of commerce and shipping.

The idea of cutting through the Panama Isthmus naturally suggested itself soon after the first exploration of Central America. It was in 1500 that Balboa, the Spaniard, first landed on the Isthmus, and in 1513 he crossed the neck on foot in twenty-three days, discovered the Pacific Ocean, and "took possession" of it in the name of the King of Spain. The Spaniards formed highways paved with stone across the Isthmus, which can be traced in places to-day; and Panama, founded in 1517, became a rich and famous city, for through it passed all the rich commerce from Peru to Spain. The spoils of the Incas traversed those stone highways.

Why the First Plans for a Panama Canal Were Put Aside

The first conception of the Panama Canal is said to have originated in those early days with one of Balboa's followers, a Spaniard named Saavedra, who made plans for submission to Charles V. of Spain. The project was found impracticable, and another plan made in the time of Philip II. was also rejected. Of the latter the story is told that Philip referred the problem to the priests, who, after profound deliberation, solved it by finding in the Bible a verse which obviously had direct reference to the matter in hand: "What therefore God hath joined together, let not man put asunder." And with that verdict canal engineering was abandoned; and certain it is that the science of that day would have been unequal to the task, even if the verdict of his religious advisers had encouraged Philip to continue.

In 1825 the great liberator Bolivar, then President of New Granada, gave a concession to Baron Thierry to construct an Isthmian Canal, but capital was not forthcoming for the enterprise. In 1838 a French company obtained a concession to make either a road, a railway, or a canal across the great obstruction, but again there was failure to start work.

The Change of View Through the Growth of the Republic Westward

Mr. H. H. Rousseau, of the United States Isthmian Canal Commission, in a report printed by the Washington Government, points out that the settlement of the northwest boundary question, by which the United States came to possess Oregon, and the Mexican War, which added California to the Union, naturally turned the eyes of the American people to the great problem of the Isthmus. The overland route to the Pacific Slope was difficult and dangerous, and the main current of immigration was deflected via Cape Horn. In order to make the newly

cquired American territory more accessible, ines of steamships from New York to the sthmus, and from the Isthmus to California and Oregon, were established by mericans, with a view to the building of a ailway across the Isthmus as a connecting ink, from which they would derive the reater part of their profits. In 1848 an merican firm secured a concession for the ailway from the State of New Granada, and ntered upon the construction of the Panama Railroad. After great difficulties, oth financial and physical, the road from spinwall—now Colon—to Panama was pened in 1855. The Panama Railroad Company secured great advantages, including the exclusive right to construct a ailway or canal within a certain area, which ave the concern complete control of the Panama route. Subsequent modification ave this control for ninety-nine years from 867. In 1848 gold was discovered in California, and the success of the Panama Railroad Company was assured. The success f the railroad and the enormous difficulty f canal construction led to the neglect of he company's canal concession.

How the British Government Retired from the Field of Competition

In 1850 an important treaty—the Bulwer-Clayton treaty—was entered into between he United Kingdom and the United States which recognised the vital importance to British interests of any project for cutting he Isthmus. This treaty was abrogated in 901, when the Hay-Pauncefote treaty ave the United States a perfectly free hand, nd Britain ruled herself out. Owning ost of the world's ships, and herself a great merican Power, the United Kingdom ormally retired from any active participation in this mighty project. Having no ntention of doing the work ourselves, it was only right that we should not prevent thers from doing it. It remains to remark hat our neglect of the subject and final etirement from the field is perhaps not ltogether creditable to the governance of he British Empire. Some of the chief West ndian Islands are British, part of the north f South America is British, the great Dominion of Canada—now possessing about ,000,000 people—is British, and, above all, ore than half the world's shipping is British. The British Empire had thus fully s much *locus standi* as the United States hen in 1901 we renounced participation in Panama Canal affairs.

To return to the situation after the signing f the Clayton-Bulwer treaty, the success of the Panama Railway did not blind the American Government to the need for a canal; and in 1869 President Grant appointed an Inter-oceanic Canal Commission. In 1870 a treaty was made between the United States and Colombia (New Granada) providing that the work should be done if a satisfactory plan could be made. The Panama Railroad Company's neglected concession was respected, and other less favourable routes, of which there were many, considered. The Commission finally decided on the Nicaraguan route, which has always been the greatest rival of the Panama plan. Their report was made in 1876, but nothing was done, and the matter was dropped.

The Life and Capital of France Poured Out in Fruitless Enterprise

Then De Lesseps took up the running, and for many years French enterprise and capital and life were poured out—largely to waste—in Central America.

A French promoter secured a concession from Colombia for the construction of a canal in 1878, and the Universal Interoceanic Canal Company was formed. The company obtained power to make the canal in any part of the Isthmus, subject to its coming to terms with the Panama Railroad Company in respect of its prior concession if the latter's territory was invaded. The Universal Interoceanic Canal Company solved this difficulty by buying up the Panama Railroad at the extravagant price of nearly £4,000,000. It was decided to construct a sea-level canal, without locks, and the cost was estimated at under £50,000,000. The work was to be done in twelve years, which would have meant completion in 1890. A preliminary capital of £12,000,000 was promptly subscribed, for the success of Suez was remembered.

How Private Enterprise Went, Through Corruption and Scandal, to Ruin

Misfortune, and worse, dogged the steps of the enterprise, and by 1889—when the canal was to have been nearly completed—the company was in bankruptcy, and the work brought to a standstill. Two years before, the sea-level plan had been abandoned and a scheme of locks substituted.

Private enterprise, which had carried through the Suez work—although with great difficulty and with much waste of money—had completely failed. The management was not only extravagant, but corrupt, and a financial scandal of the first magnitude ruined thousands of investors, and caused grievous loss to hundreds of thousands.

A New Panama Canal Company was formed in 1894, which took over the assets of the old one, and, after surveys, resumed work again. Its engineers did good work, but the undertaking was too big to be entrusted to private speculation, and it became evident that the undertaking could never command sufficient capital to complete its gigantic task.

The United States Government then took energetic action. In 1902 an Act of Congress was passed, authorising the President of the United States to acquire the assets and rights of the New Panama Canal Company at a cost not exceeding £8,000,000, and to secure from the Republic of Colombia the perpetual control of a strip of land across the Isthmus, containing the undertaking, not less than six miles wide, carrying the right to perpetually "maintain, operate, and protect" the canal. The Act authorised the President, if he failed in these negotiations, to proceed with the alternative Nicaraguan route.

The United States Government early came to terms with the French New Panama Canal Company, who agreed to take the £8,000,000. The Republic of Colombia was not so amenable, and in 1903 rejected the terms of the American Government.

Political Agitation Hand in Hand with American Business Enterprise

However, a convenient insurrection broke out in the small State of Panama, one of the provinces of the Republic of Colombia. This revolt had the moral support of the United States of America, and Colombia was, of course, helpless. America sent worships to Panama, and Colombia was not allowed to suppress the insurrection in her dominions. A "Republic" of Panama was promptly formed—total population about 300,000 men, women, and children—and with it the United States Government made the bargain which the Republic of Colombia had indignantly rejected.

The resulting geographical arrangement is peculiar. Colombia has lost one of her provinces, Panama; and Panama is an independent "Republic." Through this tiny republic there runs a strip of land, ten miles wide, containing the canal works, and within this strip the United States is lord and master. Even that part of the city of Panama which constitutes the port is within the canal zone, and therefore foreign to the "Republic" of Panama. What is alone satisfactory in this story is the fact that, by whatever means, a great and powerful nation obtained the means of prosecuting a much-needed commercial task.

The formal transfer of the French undertaking to the United States Government was made on May 4, 1904, and the great work was at last in the hands of persons strong enough to carry it through.

The course taken by the State managers has been in striking contrast to that pursued by the French speculators. The peculation and corruption of the old régime has disappeared. The first few years of the American operations were wisely devoted chiefly to making plans and putting the house in order.

A Splendid Reorganisation by Scientific American Methods

The Panama Railroad was reconstructed and double-tracked. Proper houses were erected for the army of workmen needed, for it was realised that everything depended upon efficient labour. Above all, sanitation was perfected, and the two dread diseases yellow fever and malaria tackled and beaten. What had been a fever-infested jungle was transformed into a sanitary and healthy district, in which workmen could live and work healthily and efficiently. The mosquito—two varieties of which respectively carry yellow fever and malaria—was banished from the canal zone, by draining and drying up the pools in which alone it can breed. Where the French and their men sickened and died, the Americans and their men now live in immunity. Yellow fever is unknown in the canal works, and the zone death-rate has fallen to a figure of European proportions. In two and a half years the civilisation of Panama was advanced from where it stood in the sixteenth century to a twentieth century standard. It has been a magnificent lesson in the proper way to organise industry and commerce on a large scale.

A Triumph Over Disease that Gives New Hope to the World

It may be truly said that the American triumph over disease at Panama is fully of as much importance as the triumph over mighty masses of land and water. Without the medical and sanitary triumph, the canal might never have been completed, but that is only one part of the great service which has been rendered to trade and industry. Insanitary conditions and deadly insects had much to do with beating the French, just as they had much to do with the decline of ancient Rome and ancient Greece. By making civilised life possible at Panama, the Americans have opened up

new opportunities for large and important sections of the world. If white men can live and work and trade in Central America, why not in other tropical regions? It may prove to be the case that white colonies may come to live and flourish at the tropics, and, if so, the wealth and prosperity of the world as a whole will be greatly advanced by the leading races of mankind developing latitudes where there is a continuous harvest throughout the year.

The official report of the Isthmian Canal Commission for 1911 shows that in that year the Panama canal zone had a population of over eighty-eight thousand, and that the death-rate was a fraction over fifteen per thousand, which is very nearly the death-rate of the United Kingdom. For the combined population of the cities of Panama, Colon, and the canal zone, the death-rate in 1911 was twenty-two per thousand. To show the progress that has been made, it may be mentioned that in 1907 the corresponding death-rate was forty-two per thousand. If we take the employees of the canal works alone, who now number about fifty thousand, the death-rate had fallen from nearly forty per thousand in 1907 to a fraction over eleven per thousand in 1911.

The Comparative Smallness of the Cost of a Stupendous Enterprise

The lock canal which the United States Government decided to construct, and has already advanced to a stage which makes completion within a few years a certainty, was described in detail in Chapter 16 of the Industry section of this work.

It is a remarkable fact that this gigantic and important work will be completed by the American Government for a cost which is trifling in relation to the nature and value of the scheme. They began by buying up the French company's undertaking, plus the "rights" of the Republic of Panama, for only £10,000,000.

The American estimate of the cost of completion, which is now hardly likely to be much exceeded, is £62,000,000. If we assume the real cost to be £70,000,000, we get a total of only £80,000,000. It is a small price to pay for a work which means so much for America, whether in peace or in war. The results achieved by America by the expenditure of this sum in Central America will fructify a hundredfold for American interests. In peace, her commerce and her mercantile marine will be stimulated and developed; in war, the possession of the canal will be a magnificent advantage, giving her the control of the Pacific, and making her Navy of twice its present value by making her Atlantic and Pacific seaboards practically one.

Let us now consider what will be the effect upon commerce of the cutting of the Panama Isthmus. We have first to notice that the cutting of the Suez Canal did for Britain and for Europe what the Panama Canal equally does with regard to communication with the Far East. If the Suez Canal did not exist, the Panama Canal would be a great advantage to us in communicating with the Orient. On the other hand, the Atlantic seaboard of the United States is brought much nearer to Japanese, Chinese, and other Oriental ports by the Panama route.

The Shortening of the Chief Ocean Routes for American Trade

According to official figures furnished to the Isthmian Canal Commission, the voyage from New York to Japan is shortened by 3700 miles. Now, of course, a vessel sailing from New York for the Far East uses the Suez Canal. When the Panama Canal is opened, the route from New York will be westward instead of eastward.

Or consider the effect upon the voyage from New York to Sydney. As things are, a ship now makes the voyage eastward round the Cape of Good Hope, a journey of nearly 14,000 miles. With the Panama Canal available, the voyage will be westward, and will be shortened to about ten thousand miles—a saving of about four thousand miles.

These instances help us to realise that America is a much greater gainer by the canal than Britain or any other European country. We may put it that the opening of the Panama Canal means for the Atlantic seaboard of the United States a gain in relation to the Orient and Australasia in which we share little or nothing, and which therefore is a relative gain for the United States.

The Emphasising of America's Central Position by the Canal

It should be remembered that what is true of New York is true also, within a little, of the Canadian Atlantic ports and of the West Indies. Indeed, no part of the world stands to gain more by the opening of the Panama route than the West Indian islands. The British West Indies are likely to take on a new prosperity and to gain tremendously in importance, whether for commercial or for strategical purposes.

America's central position in the world of trade will be greatly advantaged by what

will be in practice the joining up of her two fine seaboards. At present, of course, the voyage from New York to California or San Francisco means the long route round Cape Horn. After the opening of the canal, a ship leaving New York for any port north of the Panama Canal on the Pacific Coast of America will have its voyage shortened by 8400 miles, as compared with the present position. The voyage from New York to Pacific Coast ports of South America is also shortened by from one thousand to over eight thousand miles, according to whether the port is nearer to Panama or to Cape Horn.

The Great Advantage to the Pacific States of South America

In similar fashion, ports on the Pacific Coast of the United States gain in communication with South American ports on the Atlantic. A ship leaving San Francisco for South American ports makes a considerable saving via Panama as compared with the Cape Horn route.

The Pacific Coast of America also makes a gain of some magnitude for voyages to Europe. The voyage from the United Kingdom through the Panama Canal to any American Pacific ports north of Panama will be shortened by six thousand miles. Obviously, the voyage from a British or other European port makes considerable gain to South American Pacific ports via Panama, save, of course, for ports towards the southern extremity of the continent. It should be observed that the gain by a European port via Panama, as compared with via Cape Horn, for ports on the Pacific Coast of the American continent, is relatively smaller than for New York, and that therefore the Americans gain a relative advantage. Altogether, it is certainly true that America will gain much more by her enterprise than European countries.

The Relative Advantage for American Commerce Over British Commerce

In commerce, relative advantage means a great deal; and it is no little thing for America that she will rob Europe of the relative advantage which the Suez Canal gave to Europe, while gaining a further relative advantage in other directions.

If we consider the present position of Liverpool and New York in relation to San Francisco, we see that as in each case the voyage has now to be made via Cape Horn, Liverpool is almost as near to San Francisco as is New York. When the Panama Canal is available, however, New York is immediately brought two thousand seven hundred and fifty miles nearer than Liverpool to San Francisco—a position very near equality is suddenly changed into a great relative advantage for New York.

These considerations are, of course, of far more importance to the United Kingdom than to any other country. As we saw in Chapter 12, the United Kingdom now owns more than half the effective tonnage of the entire world; while the United States has an almost negligible oversea shipping. The United States is naturally fitted to be both a great shipbuilding country and a great shipping nation. It will be strange indeed if the opening of the Panama route, which will probably take place by 1915, does not make a profound alteration in the relative position of the two countries in regard to their mercantile marines.

There can be no doubt that in the past we have gained through the supineness of the Americans on the ocean. It is a case in which the United States has forgone her natural advantage. Will she continue to forgo it when she has the object-lesson before her afforded by the cutting of the Panama Isthmus? Already there seem to be signs that the Americans are alive to the great opportunity which will soon be theirs.

American Preparations to Use the Canal for Mail-Carrying Purposes

At the end of 1911 it was announced that the Atlantic and Pacific Transport Company had been incorporated, with a capital of fifteen million dollars, in order to bid for the Post Office contract for an independent mail service between the Atlantic and the Pacific, the vessels using the canal to pass from one zone to the other. The company proposes to build fifteen steamships and a considerable number of freight vessels besides a number of specially constructed steam barges, to navigate the shallow rivers and harbours of Central America. Doubtless other American shipping enterprises will be called into existence, and we may expect to see American shipowners making a serious bid for ocean traffic. The chief difficulty which will stand in their way is the want of inward cargoes, the exports of America still being much more bulky than the imports. This is a factor which is likely to right itself in the course of time.

The opening of the Panama Canal, and the consequent alteration of trade routes will undoubtedly be an important factor in the further development of South America and Mexico. The advance of South America

in the last fifteen years has been remarkable, but it is likely to be eclipsed by the almost certain developments of the next half generation. The great South American territory is still for the main part virgin ground. The Spaniards of old looked for wealth merely in the shape of precious metals; they overlooked the true Eldorado through false economic conceptions. Gold is one of the very least of the world's products, and the richest countries of the world produce little or no gold. It is the fertility and forests and mines of useful metal which constitute the real wealth of South America; and now that she is developing her water-power we may safely prophesy a magnificent future for her peoples. In this future the Panama Canal will play a great part. It is but necessary to consider the geographical situation to understand how much more readily the South American States will be able to conduct commerce when the canal is available. As a consequence they will gain more immigrants, and great white nations will come to be firmly based upon natural economic resources of a most remarkable character.

The Engineer a Greater Force in History than the Statesman

In the accompanying map, a few of the chief alterations in American trade routes are indicated in order to emphasise the extraordinary importance of the changes which the world will soon witness.

In our ordinary Mercator maps the United Kingdom is placed in the centre of the picture. In the accompanying diagram the United States is given the central position in order to show clearly its relation to the countries facing her Atlantic and Pacific seaboards respectively. We see what a wonderful position the United States will effectively occupy when her great work at Panama is accomplished.

Over and over again in the history of the modern world the engineer has had more to say than the statesman in national and international development. George Stephenson's locomotive, for example, has had far more influence upon the world than the greatest conqueror known to the world's history. The Panama Canal is an interesting example of what can be done when the statesman allies himself with the engineer. It was a case in which, as was proved in practice, the finance of the scheme was more than could be borne successfully by the credit of private individuals. The American successors of the French engineers pay tribute to the value and skill of their work. It was not the French engineers who failed, but the financial and general directors of their work. The combination, under the American régime, of wise statesmanship and skilful engineering has won the day, and given the world one of the most remarkable instances of what can be accomplished by the union of economic, engineering, and medical science. It is an object-lesson which it is hoped will make its impression upon the world, and which will doubtless set other Governments thinking of natural economic developments in their own territories. In particular, it is a lesson which should not be lost upon the British Empire, which includes some of the finest undeveloped estates in the world.

American State Development of Business a National Example for Great Britain

If the United States can do so much by an expenditure of £80,000,000 in Central America, what could not the British Empire do if it embarked upon a policy of direct Imperial development? We have seen again and again in our consideration of the world's commerce, and of the resources of the world, how limited yet is man's control of the resources of the globe. So far, world-development has been haphazard, piecemeal, almost purposeless. Small bodies of men here and there, with limited resources and insufficient capitals, have chipped and scratched at problems which need large-scale handling. In the future we shall undoubtedly see more of national control of national resources, as it is realised that the maintenance of civilisation by enormous populations demands the constant supply of materials on a gigantic scale, and therefore the conscious conservation of the world's wealth for the public good.

The National Organisation of Human Effort in its Struggle with Nature

The campaigns of the past have been between races or nations of men. The campaigns of the future will be organised contests between Great Powers on the one hand, exercising the collective force of millions of men, and the forces of Nature on the other hand. Civilisation has been only partially successful in the past, because men have wasted so much of their strength in contest with each other. The struggle with Nature cannot be waged with greater success without an organised campaign. At Panama we have seen what can be done by man when he faces Nature with determination, without the handicap of private interest, and with the single aim of achieving a great national end.

DAWN OF THE SCIENTIFIC CURIOSITY WHICH HAS RESULTED IN MODERN INVENTION

DR. WILLIAM GILBERT, PRESIDENT OF THE COLLEGE OF PHYSICIANS, SHOWING HIS EXPERIMENTS IN ELECTRICITY TO QUEEN ELIZABETH

SOCIETY AND INVENTORS

The Origin of the Industrial Revolution that is Transforming the Modern World

WHAT A PEOPLE WINS BY LIBERTY

WHAT is the prize that a people wins when it has slowly and painfully transformed its old coercive forms of government into a new system of free institutions? Is it happiness? Is it wealth? Is it power?

Well, the British nation is distinguished for the spirit of liberty that pervades all the departments of its social life. For some centuries it has possessed a form of government freer than that of any other great civilised race. Practically all the modern machinery of political liberty has been conserved and developed by our forefathers and ourselves and our kinsmen far scattered over the seas. Even the French Revolution, that shattered the feudal structure of Continental Europe, was only a partial manifestation of the new spirit of liberty created in the conscience of the Anglo-Celtic race. Here and there, perhaps, another nation has bettered the ideas she learnt from us, but on the whole our race is still leading the way in the evolution of free institutions.

Yet it is very doubtful if we are as happy as the more backward races of the world, with their simple needs, their quiet life of routine, and their pleasant and leisurely ways of existence. Exempt from the fever of the soul and the turmoil of the spirit, that trouble and weaken many of the best minds of all our classes, they form reservoirs of mental and physical force from which human society will draw a new supply of strength when we perhaps fail and fall under the burden of progress. Already it seems likely that some of the backward races of Europe, now streaming in emigrant ships to the United States, will in a few generations be carrying on the civilisation founded by British settlers.

Surely it is not happiness that the Anglo-Celtic race has won by its long and victorious struggle for liberty. And can it be said that our people generally have gained the prize of great wealth? It is a notorious fact that one third of the population of the mother-country is suffering severely from poverty. They, at least, have won very little happiness or riches by the development of free institutions. The English serf of the Middle Ages was often more fortunate in the conditions of his life than is many a free labourer of modern England. He had land from which to win his food, pleasant and healthy surroundings, and many occasions for rural sports and pastimes. Enormous as is the wealth of our country as a whole, it can scarcely be maintained that the actual proportion of the means of living among the various classes of our population has been increased in a way favourable to a general prosperity.

So, if we are candid, we shall be inclined to admit that after some centuries of freer government than any other large nation, ancient or modern, ever enjoyed, we have not generally become happier and richer than we used to be. Merry England has long since disappeared; we have lost that lively sense of the joy in life that we shared with mediæval Christendom. We have become rather sombre-minded, and, maybe, more hard-working, and certainly more ambitious of material success than our ancestors were under feudal rule; and we have forgotten the art of taking life easily and pleasantly and naturally. But it will be said that our nation is immensely more powerful than it was in the days of its subjection to coercive government. Looking at the matter in one way, this is undoubtedly true. As has been already pointed out, we have grown in about three hundred years from a nation of five million souls into a group of states and dependencies with a population of 530 millions.

On the other hand, our actual military power has not increased in proportion. Under feudal government we were mighty upon the Continent. Our military organisation was such that, again and again, we were able to raise an expeditionary force capable of conquering a powerful and wealthy kingdom. We were almost as strong on land as modern Germany is, and for somewhat the same reason. Our people were drilled to habits of obedience and directed to predatory conquests by a feudal war-lord. Modern Germany is an incarnation of the old feudal spirit, armed with all the resources of modern civilisation. Prussia became a mediæval State at a time when the rest of Europe was growing modern in thought and feeling. By building up a new and mighty empire on an improved feudal system, she has quickly won an ascendency over the surrounding nations, which in turn has compelled many of them also to revive and extend the old military coercive forms of social organisation. Great Britain has escaped from this modern sort of militarism, solely by reason of her happy insular position. But, far from having any real power in Continental affairs, she is compelled to stand anxiously on the defence against aggression, with only a slight superiority in the number of her latest battleships to deter a possible enemy from attacking her.

Inventiveness the Great Modern Outcome of the British Spirit of Liberty

So in actual military power modern Britain, the birthplace of the new spirit of liberty, is vastly inferior to the predatory feudal island kingdom that seized a great part of France and a portion of Flanders.

What, then, is the prize that she has won by being the first large nation to work out a form of government animated by the spirit of liberty? In the opinion of the present writer the grand quality of a law-abiding, alert, and free people is inventiveness. Of course, there are many other things that go with liberty, but they are direct attributes of a state of freedom rather than a new and extraordinary social power produced by the effects of free institutions on the popular mind. A genius for invention, however, is a kind of prize that a people wins when it combines the habit of co-operation with the marvellous power of personal initiative which finds a universal scope only under free and equal government

Many writers have contrasted the beneficent power of a single enlightened and able ruler with the slow progress made in certain social reforms by a free people. A large body of men who settle things by discussion instead of by coercive commands is bound to be often slower in moving in a right direction than a despot of genius. And it must be admitted that, in matters requiring instant decision and swiftness of execution, a centralised government will possess a great advantage over a nation that does not act under orders.

Despotism—Power Without Inspiration or Originality

This is not the case only in war, but in many important social reforms. A man who wields an absolute State control can effect in a few years new movements of high importance, which a generation of free people could not engineer to a full end. The present condition of Great Britain is proof of this. Its social scheme has so many gross and flagrant defects that the woeful spectacle of them has made many men besides Thomas Carlyle long for the swift and trenchant rule of a reforming despot. But a despot, after all, is only a single man; and it is very occasionally that he combines a genius for reform with a natural passion for power. A despot seldom originates. He is power without inspiration. He is sometimes a good organiser; and if he is served by a Minister with a large experience of the needs of the people he may distinguish himself in domestic affairs as well as in wars of conquest.

On the other hand, when some millions of free men have received the impetus of mind that true liberty gives, they can often accomplish very wonderful things. Each man may be apparently bent on personal ambitions; but in the free play of his intellect over matters of his own experience he is continually adding to the resources of the human race.

Modern Industry the Fruit of Invention Due to Individual Initiative

It is often said that the growth of industrialism is the force behind the modern movement of freedom. But we are inclined to put it the other way. When the Roman Empire was rotting into a despotism, the industries and commerce of the people were much superior to those of the English nation in the days of its early struggle for free institutions. If industrialism pure and simple has done such good work in the modern world, why were few or none of its effects on political institutions visible in all the great despotic civilisations of the

THE MAYPOLE DANCE AND VILLAGE SPORTS OF SIXTEENTH CENTURY ENGLAND

ancient world? Our view is that modern industry is the fruit of invention of a very high order; and this extraordinary inventiveness is directly due to the development of individual initiative and individual versatility of mind, elicited by a new spirit of liberty that is partly religious in origin.

Indeed, we will go farther, and say that the modern industrial revolution has a different beginning and a different direction from that of the industrial movements in ancient civilisations. It arose through no national necessity. The fact was that our best minds could not help inventing, any more than they could help thinking.

The Enthusiasm for Invention a Revival of Elizabethan Zest

Excited to enthusiasm by the new influences at work in their political and social life, they gave their intellectual powers full play, with just the same zest as the Elizabethans, at the dawn of the new age, gave scope to their poetic genius and scientific curiosity. But this time it was not a renaissance—a rebirth of the ancient arts, but a new creation.

The Greek was inspired by a keen feeling of personal liberty that did not prevent him from living on slave labour. All that he aimed at was to make his own life beautiful; he had little care for the future of mankind; and at the height of his thought he could get no farther than the idea of a pleasant little Utopia, in which the working people were kept in subjection by cunning falsehoods backed by the military power of the superior class. Such, at least, is the ideal state of which Plato dreamed. Beautiful Greek life was, but its beauty was that of a flower rooted in slime.

The Qualities of the Briton of the Latter Part of the Eighteenth Century

The Briton of the eighteenth century was not lacking in a sense of beauty, as the exquisite furniture of his making shows. He was indeed one of the finest craftsmen in the world, and his feeling for pure loveliness of line was extraordinarily fine. In portrait-painting, his artists were comparable with the greatest men of the Renaissance; in landscape painting, one Englishman, Turner, rose to an unrivalled height of poetic power of interpretation; in literature, Burke and Wordsworth clothed the ideas and aspirations of the age with a glorious beauty of language. The Briton of the eighteenth century had a much finer æsthetic sense generally than we possess; but when he came to work out his large inventions he set usefulness above beauty. For he began to see he was acquiring mighty powers that would change the destinies of the human race.

On the one hand, he started an agitation for putting down the slave trade, and, on the other hand, he proceeded to invent and build wonderful iron slaves that could do much of the hard, brutalising work the necessity for which had kept a very large part of the human race in mental and physical subjection. At first he used the power of running water to impel his new machinery; and it was not till long after the invention of Watt's steam-engine that steam power was generally applied for manufacturing purposes. For instance, the steam-engine was first used in a cotton factory in 1785, but the handloom weaver was not displaced by the operative for many years. It was only in 1840 that the power-loom was clearly seen to be triumphant.

Transformation of National Life by the Inventive Genius of a Free People

It took about a hundred years for the industrial revolution to gather force, and sweep the country craftsman into the sombre factory town. In the meantime, the inventive genius of a free and powerful people, brimming over with personal initiative and individual ambition, was transforming the national life in various other directions. We have already described the great agricultural revolution they accomplished, which enabled them to plough through vast and virgin continents at a marvellous speed. It would have been utterly impossible for a despot of the highest genius to have carried out a hundredth part of the tremendous changes in the conditions of human life which the Anglo-Celtic race effected merely by the free exercise of its manifold and far-reaching genius.

Legislation was thoroughly worked out on a new principle by a single London thinker, Jeremy Bentham; and a few disciples of his succeeded in softening our old harsh laws, and changing the national point of view in regard to penal enactments.

The same thinker, starting without any influence whatever, also created and promoted a thorough reformation of the British system of government. By cleansing Parliament of its worst corruptions, and placing it on a larger popular basis, he instituted the actual, practical democratic movement in British politics. He died in the year in which the first great Reform Bill was passed, and through a thousand channels his influence continued to affect the thought and polity of the country.

On the other hand, this private man of obscure position, who remained all his life unknown to the people he was acting on, was only one of a group of powerful thinkers who, by sheer inventive force of mind, began to cast into a new mould the structure of British society. Opposed to Bentham, the father of modern Radicalism, was Edmund Burke, the author of the modern Conservative movement. All that was fruitful and valid and efficacious in eighteenth century thought of the traditional kind was collected and fused and transformed by the Shakespearean genius of Burke, and fashioned into a new force that interplayed with the forces of Benthamism, and changed a revolutionary process into the more gradual but more permanent process of evolution.

Thus, out of the clash and conflict of inventive minds with different views, a swift and diverse movement of progress was promoted. There was scarcely a department of national life that was not affected. New currents of inspiration were generally felt in art and literature. British science recovered from the strange stagnation into which it had fallen since the days of Newton, and again became vigorous and fertile in discoveries that changed the thought of the world, and opened out new lines of research from which the human race has derived fresh and astonishing sources of power and knowledge. A stream of new ideas played upon the political and social life of the nation; and a series of new inventions in agriculture and industry so altered the economic conditions of the people that the entire structure of their civilisation had partly to be repaired, but much more largely rebuilt. Even in matters of religion new forces of various kinds began strongly to work. In short, the soul and the mind, the work and the Government, the character and the mode of life of the nation, were modified by an outburst of inventiveness which is without parallel in the history of mankind. The thing was not planned and calculated and ordered. It was simply an enormous and unexpected explosion of intellectual energy, produced by the lightning of liberty striking on the general mind. It would not be true to stay that all this creative activity of free thought was unaccompanied by any loosening of the ancient habits of co-operation. There was considerable unsettlement, and some dreadful abuses occurred. Hundreds of thousands of skilled craftsmen were deprived of their means of livelihood; and in the days when water-power was largely employed in certain industries, child labour was often used in a cruel and shameful manner. The State was at last compelled to resume some of its old coercive powers over individual enterprise, in order to enforce upon a large body of the people the social duties they had neglected to observe.

JEREMY BENTHAM

EDMUND BURKE

Even at the present day there seems to be need for more State control in the interests of the future welfare of the race. But the nation must be careful of returning to the mediæval idea of Government direction and supervision. Here the example of modern Germany is apt to be misleading. Germany has recently won so remarkable an amount of military power and industrial efficiency by an able system of coercive and directive regulation of all its national forces that many thoughtful persons in our country would like to reorganise Great Britain on the German model. This could certainly be done. Moreover, it would not be difficult to introduce into the British scheme a liberal and democratic spirit which would commend it to a large body of electors. But some of our leading men of science are now passionately protesting against the new German gospel of administrative efficiency. And in our opinion their protests are well founded.

A capable and intelligent bureaucracy, with mediæval powers of control over every department of the nation's activities, may seem very effective for a generation or two. Armed with the ideas and inventions of the whole civilised world, and assisted by the advice of many professors of science, it can

for a while realise the dreams of many English statesmen from the Tudor to the Georgian period, and drill the country into an apparently high state of general efficiency. But, since the days of Adam Smith, this thorough policy of State control, with its continual interference with the economic liberty of a people, has been found by us to be momentarily successful but permanently disastrous. No doubt, the gospel of individualism was developed by our grandfathers to an extravagant degree. None the less, it was originally inspired by true feeling and sound knowledge. The feeling of the value of personal freedom, and the knowledge of the very grave disadvantages of continual State interference, were at the bottom of the general dissatisfaction with the Government direction of the economic forces of the nation.

Our Government once tried to develop the fishing industries by making a law compelling every person to eat fish on two days of every week in the year! It regulated the dress of the various classes, to prevent vain extravagance. Up to the beginning of the reign of George III., there was a great system of commercial and industrial organisation that dealt with every side of the industrial life of the kingdom.

The Past Failures to Organise Life by State Interference

Parliament expended an immense amount of care on the national direction of all enterprises that helped to build up the power of the country. Special attention was given to the food supply; the proper training of workmen was provided for; and there was on paper, at least some machinery for insuring them a minimum wage; and those persons who were unable or unwilling to work were kept from starvation by means of the Poor Law.

This system was quite as admirable as that of modern Germany. It made for the same kind of national efficiency, and, on the whole, it kept England strong in both industrial and military power. Yet it was overthrown and completely broken up by the general genius for invention that suddenly inspired the people when they had developed their free institutions to the point at which they became aware of the deeper influences of the spirit of liberty.

They were fairly happy, they were fairly comfortable, and they were very prosperous. None of the nations around them was so firmly settled and so well off. Yet they could not rest content; and so they applied their new powers of invention in engineering a revolution in their national life, compared with which the French Revolution was but a little, transient class war. The fact was that the British nation did not know what it was doing. It had become the unconscious instrument of the spirit of liberty; and, instead of working entirely for its own advantage, it began blindly and yet strenuously to labour in the cause of humanity.

The Unexpected Social Drawbacks That Have Accompanied the Reign of Invention

The last hundred years of our national life have been marked by much general suffering and general unrest. This suffering and this unrest are a direct result of the inventiveness of the race. It is inventions which have destroyed the handicrafts that enabled a large proportion of the people to live in a fairly independent manner, eking out the profit from their small holdings by some kind of village industry. It is inventions which have robbed one-third of the population of adequate means of subsistence, and turned hundreds of thousands of skilled craftsmen, who took a joy in their work, into a multitude of factory operatives spending their lives in dull, machine-like labour. It is inventions, in both the organisation of industry and in industry appliances, that have obscured the kindly social bond between the man who does a piece of work and the man who buys that piece of work. Between the actual producer and the actual consumer there now often intervenes a complex and remote web of collecting and distributing agencies which reduce all the mutual helpfulness that keeps together a great civilisation into a matter of money. The cheap shop, built often on the foulness and injustice of the sweating den, is sometimes the most garish and popular centre of trade in a modern city.

The Machine that has Become a Curse Must be Made a Blessing

The invention of new systems of organisation has aggravated the effect produced by the invention of new mechanisms of labour. The general result is that man has become the slave of the machine; and great have been the unsettlement, the unrest, and the suffering. This has led Ruskin and his followers to condemn the invention of the modern machine, and attempt to found again the ancient arts of the peasantry. It does not, however, seem likely that the old condition of things will ever be restored. Frankenstein will not destroy the strange monster of steel that he has set working. Practically speaking, it is now beyond his

power to do so. Not less invention, but more invention, is needed. The machine which has destroyed so much of the past, and created confusion in the present, must be made to build up the future. If all goes well, the humblest farm labourer, a hundred years hence, will find himself in a happier position than his forefathers were a hundred years ago. For he will be the master of a metal slave, cheaply but strongly built, and driven by a cheap supply of power, which will enfranchise him from all the severe and brain-deadening part of his labours, and win him leisure and means for sweetening and liberalising recreations. The enormous factory towns will again be resolved into little industrial groups, scattered over the country-side and partly re-attached to the soil. And the great commercial cities will go on spreading for hundreds of miles, along motor-roads and high-speed railways, until they will be lost in the woodlands and the farm-lands continually intervening between the clusters of red-roofed and white-walled houses.

In other words, we are living in an age of transition between a dead world and a world still in travail of birth. Neither statesman nor prophet can of themselves get us out of the muddle into which we have fallen. Yet both can greatly assist, one by practising, and the other by preaching, the religion of true liberty. Our generation needs uplifting by another wave of inspiration, hope, and enthusiasm. The popular mind must be touched again with a Divine fire, and set to work with a renewed genius for invention in all the departments of national life. The task that the men of the eighteenth century partly accomplished must be carried to its full end in the next three generations. As the State does not invent, the State cannot help us here.

All that fosters the individual initiative, with its innumerable experiments, enterprises, and adventures; all that elicits from a man powers of mind that he did not himself suspect; all that shows how the manifold experiences and essays and insights of a free and law-abiding people can put to shame the well-thought-out plans of the most enlightened bureaucracy; all that justifies liberty of her children, is needed to save the Anglo-Celtic race from falling by the way when its noble and mighty task is scarcely half carried through. We must show that the inventive power of a free people is more permanently effective than the organisation for efficiency which the Prussian is undertaking throughout Germany. If we fail to do so, it may be many hundreds of years before liberty becomes again the mightiest force in the world of actual affairs.

A TYPICAL TAILORS' SWEATING DEN IN THE EAST END OF LONDON

THE GOLDEN AGE: AN ARTIST'S VISION OF A SPRINGTIDE IN THE CHILDHOOD OF THE WORLD

"WHEN THE WORLD WAS YOUNG" BY ANNA LEA MERRITT

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EUGENICS AND THE FAMILY

The Need for the Organised Study in this Country of Individual Cases of Heredity

MODERN KNOWLEDGE OF HUMAN HEREDITY

We have found that Darwinism, and the theories of heredity upon which it was based half a century and more ago, cannot furnish a sure basis for Natural Eugenics; and we are already convinced that we shall do far more harm than good if we begin to dictate to the public on grounds which cannot be sustained. "Back to the individual" must be our motto; for what we have to deal with, in practice, is the individual man or woman. Should he or she marry or not marry? Are there any particular kinds of person, quite suitable in themselves, whom he or she should not marry? And so on. On paper it is easy to sort mankind into classes, and label them accordingly. In practice the unique individual confronts us.

Now, the modern study of heredity is distinguished, above all, by just the same principle. "Back to the individual" is its motto also. We have found that analysis of the individual case is the only way in which heredity can be understood, and that this is as true of mankind as of any other species. All this involves most important consequences for eugenics, incalculably to its advantage.

The change of position is very recent, and may best be illustrated by comparing the present situation with that represented by Sir Francis Galton's Herbert Spencer Lecture at Oxford in 1907, which was entitled "Probability, the Foundation of Eugenics." There he sought to apply the laws of chance to the problems of human heredity, considered the case of a stock or class of persons afflicted with degeneracy, and showed how we might ascertain a kind of measure of the average degree of damage which the offspring of such persons might do. The problem for the Eugenist would thus be to satisfy the community that the average expectation of mischief done would justify the taking of drastic measures against the propagation of such persons. Now, that was all very well so long as we were entitled to speak of "degenerate stocks," or classes, in that summary way; and the mathematicians were doubtless right in trying to measure average degrees of kinship and similarity and expectancy of transmission.

But the case is entirely changed today, when we find the startling results obtained by individual analysis of each case, on the principles which Mendel practised long ago. Of two brothers one may have a definite defect, which he is liable to transmit; and the other may be free of that defect, and incapable of transmitting it. According to the older views, and according to the biometricians today, both those individuals belong to a defective stock; and the average intensity of inheritance is quoted as showing a probability that their offspring will be defective. To which the reply is that these brothers are yet different, like the peas in Mendel's pods; and the facts are that the offspring of the one are *certain* to show his defect in a proportion of cases, while the offspring of the other are *certain* not to. This is a great change and a great advance. Only by investigation along these lines, and the provision of a sufficiency of detailed pedigrees, will the eugenics of the future be able rightly to convince public opinion, and to encourage and discourage parenthood not *en masse*, as if human beings were as similar as atoms of oxygen, but with real discrimination for each individual case.

A distinguished American biologist, Dr. Raymond Pearl, read a paper on this subject before the annual meeting of the American Association for the Study and Prevention of Infant Mortality; and as Dr. Pearl used to be a biometrician, and has been largely quoted by biometricians, it is worth

our while to observe how the development of knowledge has compelled him to change his views. He points out that statistical statements regarding human inheritance are not useful for eugenics, for the obvious reason that the real problems of eugenics are concerned not with masses but with individuals. The reason why we seek the laws of human inheritance is not in order to repeat them to ourselves, but the real, compelling, human reason why we want to know these laws is that we may be able to predict with precision what will happen in the individual case.

Testimony of an American Convert from Statistical to Individual Methods of Study

"The statistician will tell us that all this is nonsense—a chimerical dream—because in inheritance the results are determined by an indefinitely vast number of small causes all acting together, and hence anything like accurate prediction of results in the individual case is quite out of the question. This argument has plausibility, and has carried weight. Latterly, however, it has lost much of its force. It is perfectly true that by statistical methods it is apparently impossible to get at any general law whereby one can predict the coat-colour of offspring, horses or dogs (for example) following particular, individual matings. Yet it is evident that the difficulty here does not inhere in the nature of the case, but rather in the nature of the methods. By direct and 'individualistic' methods of research a general law has been worked out wherefrom one is, in point of fact, able to predict the coat-colour of horses and dogs in the individual case."

Why Averaging Results of Observation is Unsatisfactory for the Individual and for Society

This is a very notable statement by one who was formerly a biometrician, and its practical significance will be evident. As Dr. Pearl says further on: "The fruitfulness of this method of attacking the problem of human inheritance is particularly evident in the case of disease. Nowhere is information of an 'average' character more unsatisfactory, both for the individual and for society. To find, as has been done, that certain pathological conditions and abnormalities of structure and function in man are inherited definitely and clearly along Mendelian lines is an achievement of great value. Such a result is of significance both for the race and for the individual. If there is a definite and clear-cut segregation of the abnormal and the normal within a tainted stock, it means for the race the conservation of the useful energies of the progeny of those germinally segregated, normal individuals who, under the sweeping condemnation of tainted stocks which a purely statistical eugenics advocates, would be prevented, if possible, from reproducing themselves. To the normal individual who segregates out of a tainted stock it means a life of normal, hopeful usefulness, in the place of the haunting fear or dread of 'heredity.'"

Rather than express this advance in our own words, we have preferred to quote at length from one who has been hitherto the most distinguished disciple of Professor Karl Pearson on the other side of the Atlantic, and whose work on some humble animal forms was corroborative of Professor Pearson's important theory of "homogamy," or the tendency, which he appears to have proved, for like to mate with like. Dr. Raymond Pearl's new attitude towards statistical methods, and his acceptance of what what we now call genetics, offers testimony of a very special kind to the views which have long been held by the present writer; and we shall later see that Dr. Pearl's position is confirmed by the very important work now being done by the American school of eugenics.

Our Knowledge of Eugenics not Wide Enough to Warrant Interference with Social Habits

How far, then, will the real knowledge of the present carry us? Its quality is beyond question, but what of its quantity? This is a serious matter, considering the immense range of the structure of positive and negative eugenics which we desire to erect upon our knowledge of human heredity. The reader will most certainly be disappointed at this stage if he had formed hopes commensurate with the sweeping generalisations of the biometricians. We undoubtedly know more to-day than we did five years ago, but we also know that we know much less than many had thought. Here, for instance, are the words, not improbably surprising to the reader, in which Professor Bateson expresses his present position. They are taken from the Herbert Spencer Lecture for 1912, and notably contrast with the assumptions contained in Sir Francis Galton's Herbert Spencer Lecture for 1907, to which we have already referred. Professor Bateson says:

"May I clear myself at once of a possible misunderstanding? You will think, perhaps, that I am about to advocate interference by the State, or by public opinion, with the ordinary practices and habits of our society. There may be some who think that the English would be happier if their marriages were arranged at Westminster instead of, as hitherto,

in heaven. I am not of that opinion, nor can I suppose that the constructive proposals even of the less advanced Eugenists would be seriously supported by anyone who realised how slender is our present knowledge of the details of the genetic processes in their application to man. Before science can claim to have any positive guidance to offer, numbers of untouched problems must be solved. We need first some outline of an analysis of human characters, to know which are due to the presence of positive factors, and which are due to their absence; how and in respect of what qualities the still mysterious phenomenon of sex causes departures from the simpler rules of descent, and many other data which will occur readily enough to those who are familiar with these inquiries. It is almost certain, for instance, that some qualities are transmitted differently according as they are possessed by the mother or by the father; and it is by no means improbable that various forms of conspicuous talent are among their number."

Segregation of the Hopelessly Unfit the Limit of the Advance of Science

A further paragraph from this important lecture must be quoted, partly because of its urgent practical importance, and partly as the most recent pronouncement of our first authority on the relation of modern knowledge of heredity to practical eugenics. Professor Bateson says:

"As regards practical interference, there is, nevertheless, one perfectly clear line of action which we may be agreed to take—the segregation of the hopelessly unfit. I need not argue this point. When it is realised that two parents, both of gravely defective or feeble mind, in the usual acceptance of that term, *do not have any normal children at all*, save perhaps in some very rare cases, and that the offspring of even one such parent mated to a normal generally contains a proportion of defectives, no one can doubt that the right and most humane policy is to restrain them from breeding; and I suppose the principle of the Act now before Parliament for the institution of such a policy will have general approval. Under our present system the State exerts all the powers which science has developed for the preservation of such persons from their birth, most of whom would otherwise perish early. Brought to maturity, their destiny is not difficult to imagine. However ignorant we may be as to the several ingredients which are required to compose a stable society, or of the proportions in which they are severally desirable, we are safe in preventing these creatures from reproducing themselves. Some of the more advanced of the American States are already going further; and even such a representative of older ideas as the State of New Jersey is, I am informed, introducing the practice of sterilising criminals of special classes. That appears to me the very utmost length to which it is safe to extend legislative interference of this kind, until social physiology has been much more fully explored. Beyond that, if there is authority to go, it is not drawn from genetic science."

How Science Forces Us Back upon a Study of the Individual

The full consequences of the abandonment of biometry, and the substitution of genetics as the primary foundation of eugenics, have yet been realised by very few Eugenists. Science forces us back upon the individual, and we have hitherto been talking of stocks and even of social classes. Eugenics began, in the mind of Sir Francis Galton, as a cultivation of valuable stocks, or "stirps"; hence his introduction of the word "stirpiculture," for which he later substituted eugenics. It was made clear, by his early researches, that average differences between various stocks of families do exist, and are of a large order. Thus, for instance, the Darwin stock, of which Galton was himself a representative, has produced a quite exceptional number of valuable individuals in the course of the last four generations: and many more of the same kind have been investigated. At the other end of the scale we have the record of the Jukes family, in America, with its output of degenerates. From first to last, eugenics meant, for Sir Francis Galton, above all the encouragement of worthy stocks; and "negative eugenics," when he accepted that term and what it involves from the present writer, similarly meant for him the discouragement of unworthy stocks.

Impossibility of Framing Repressive Measures Based upon Human Stocks

But we begin to see now that it is impossible to frame measures of eugenic action on these categories. It would be impossible, even if the members of any stock never married outside it, and it is all the more impossible since, of course, stocks intermarry. We are rapidly learning that the special characteristics of mind or body which distinguish us from each other are distributed through any given stock not at random, nor generally, nor by chance, but according to certain laws of fixed proportions. Thus there will be a proportion of mediocre individuals, or worse, even in the most distinguished families, and there will be normal individuals in tainted stocks.

A case in point is furnished by the recent American observation of certain entirely sane, healthy, and well-behaved members of the "Jukes stock," which has been quoted so many hundreds of times without discrimination. As Dr. Raymond Pearl has pointed out, perfectly normal individuals may segregate out of tainted stocks; and if eugenics is ever to be useful and acceptable it must recognise that exceedingly satisfactory fact.

The Necessity for the Study of Feeble-Mindedness upon Mendel's Lines

The case of feeble-mindedness, to which Professor Bateson refers in the foregoing quotation, and about which we shall have to say so much when we come to the practice of negative eugenics, furnishes an important illustration of the present argument. Modern inquiry, especially by the American school, has shown that feeble-mindedness is a comparatively simple thing, so far as hereditary transmission is concerned. It is probably due to the absence of only one, or at most two, "factors," as the Mendelians call them, from the germ-cells which convey this defect. When the defect exists on both sides, as we have seen, the children are all defective. But when it exists on one side only, a proportion of the children are normal. Nor do we find feeble-minded pedigrees in which normal individuals do not occur. It is therefore essential that we should study such pedigrees more closely, that we should investigate the antecedents of each case on Mendelian lines, and only then shall we be able to prescribe a genuine eugenics.

The Difficulty of Giving Positive Encouragement to the Fit on Eugenic Lines

Already we cannot doubt regarding those who themselves exhibit the defect; but what are we to urge regarding their normal brothers and sisters? Of these, in the case of this and many other defects, it may appear that some are not only normal in themselves but will have only normal offspring, while others, though personally normal, may be liable to have a proportion of defective children. All these cases must be distinguished; and with the recognition of that necessity there goes the case for any indiscriminate "stock" eugenics, or stirpiculture, as based on statistical probability estimated by confounding different things and taking the average of them.

Just similar is the verdict of modern study upon the acceptance of stock in this fashion when we turn to desirable qualities, only that here the argument against sweeping generalisations is still more powerful. In the case of feeble-mindedness, and, as we shall see, of a number of other defects, the quality we seek to arrest is comparatively definite in its genetic causation, and can not infrequently be recognised as due to the presence, or the absence, of a simple genetic factor. In such cases, where the system of transmission is proportionately simple, our interference could be made apt and efficient. Far otherwise is it with what we have agreed to call positive eugenics, though the fact may be disappointing to many enthusiasts. Professor Bateson came to this conclusion two years ago, at the end of his great work on "Mendel's Principles of Heredity," where, after referring to the possibilities of negative eugenics, in the light of modern knowledge, he goes on to say: "More extensive schemes are already being advocated by writers who are neither utopians nor visionaries. Their proposals are directed in the belief that society is more likely to accept a positive plan for the encouragement of the fit than negative interference for the restraint of the unfit. Genetic science, as I have said, gives no clear sanction to these proposals."

The Special Difficulty of Tracing the Origin of Admirable Mental Qualities

The reason for this cautious conclusion as to the immediate possibilities of positive eugenics is clear when we come to study the desirable characteristics which we desire to encourage. The great contrast between them and the morbid and objectionable characters, as a whole, is that these valuable ones are complicated in their nature. It is possible that the absence or presence of only one genetic factor may constitute the difference between feeble-mindedness and normal mind, but it is very certain that, say, "conscientiousness" cannot be so traced. True, this characteristic, and many others of equal complexity, have been treated as units by the biometricians, and the statistical rate of their transmission has been calculated. But such vagaries are better forgotten.

The recent work of such psychologists as Dr. McDougall, to say nothing of common sense and ordinary experience, has shown us that most admirable mental qualities, and probably most admirable physical qualities also, are not unitary but complex, owing their appearance to the harmonious co-existence of more factors than one in the genetic constitution of the

individual. In Professor Bateson's own words, which recent psychology entirely corroborates: "There is as yet nothing in the descent of the higher mental qualities to suggest that they follow any simple system of transmission. It is likely that both they and the more marked developments of physical powers result rather from the coincidence of numerous factors than from the possession of any one genetic element."

The Complexity of the Elements that Combine in a Fine Character

Let us not lack the sense of proportion which will remind us that this is not exactly a discovery of modern science! It is as old as genuine observation; and a classical instance of the expression of this idea is to be found, we need hardly say, in Shakespeare, where Antony pronounces his few noble lines on Brutus:

"His life was gentle; and the elements
So mix'd in him, that Nature might stand up,
And say to all the world, *This was a man!*"

Now let us observe what this conception of the genetic constitution of fine qualities must mean for eugenics. There may be exceptions to it, no doubt; and there is some evidence to show that musical faculty (or some constituents of a complete musical endowment, which is very rare) may depend upon a single genetic factor. But on the whole this statement of the genetic complexity of fine qualities must be accepted. It gravely qualifies the prospects of positive eugenics. If each unit forming one of these complexes follows the Mendelian law in transmission, we see how seldom our hopes would be realised, for it cannot often chance that all the necessary units come together again in a germ-cell, and then there are all the possibilities that depend upon the particular constitution of the germ-cell with which the first is mated.

The Prevalence of Hereditary Ability Admitted, but not of Hereditary Genius

Here, of course, is the explanation of the countless disappointments which we suffer when we observe the offspring of distinguished persons, and find how ordinary they are. The various units that met in the rare person, and combined to give him or her the quality we prize, have now segregated or separated; and in the offspring "the elements are so mixed" that there is nothing notable or exceptional at all. The contrast between such cases and those of some disease, say hæmophilia, due to a single genetic factor, where the undesirable quality reappears with mathematical regularity, are ironic and deeply significant; and the simple explanation of them is now forthcoming.

We now begin to understand the rarity of genius. If it depended upon the presence or absence of a single genetic factor, or even of only two or three, it would be common. We see, also, that we must be very careful as to what we predict and promise from our eugenic activities. Serious harm has been done by the fact that Sir Francis Galton, when he put together his early researches in the form of a book, gave it the title of "Hereditary Genius." The title conveys a totally wrong impression of what the book really contains. It does largely show the inheritance of *ability;* and Sir Francis Galton himself observed, in the preface of the second edition, that if possible he would change the title of the book to "Hereditary Ability." By just so much as mere ability is commoner than genius may we guess that it depends upon the coming together of fewer genetic factors, and that its appearance in any stock will therefore be more frequent, though we note that in no case can we expect it to appear in every member of any stock.

The Impossibility of Combining Qualities so as to Breed Genius

It follows that we shall have no discussion, in the succeeding chapters, of the fashion in which positive eugenics proposes to apply the laws of heredity for the production of Newtons and Shakespeares. This is a delusion to which some Eugenists are prone, and it constitutes a serious obstacle for the sane advocates of eugenics, who are constantly met with inquiries as to the breeding of genius, and with questions as to this or that case—and their name is legion—where the child of a genius was a mediocrity. Naturally, also, the critics of eugenics do not trouble to distinguish between its responsible and irresponsible advocates, and expend their sarcasm upon proposals and expectations which every sensible Eugenist is constantly repudiating. In a word, we believe that we can breed out feeble-mindedness, because that is simple, but we know that we cannot produce genius by any system, not even if we could treat mankind as Mendel treated peas, because genius is complicated, and proportionately beyond our control. Thus, supposing that any particular kind of genius required the combination of only five factors, it might easily

be shown that perhaps only one such genius could be expected, on the average, among perhaps a hundred or more offspring of parents in whom those factors might be expected to exist. The relatively tiny numbers of human offspring are thus an obstacle; and in the case we suggest it might well be that the combination of, say, any four of those factors in an individual might yield, instead of a genius, only some particularly flagrant kind of fool.

The Unsoundness of Generalisations in Eugenics on a Class Basis

If such arguments, drawn from the modern conceptions of genetics, compel us to abandon even the idea of stocks, on the ground that any kind of stock will contain sharply contrasted individuals, of vastly different worth, how much more is class-eugenics, the poisonous growth which has sprung up since the death of Galton, condemned by such conceptions! Yet the fact remains that, just when modern genetics is giving us a scientific explanation of the familiar fact that the offspring of even the same parents differ widely among themselves, some recent writers are asking us to accept social classes, and to reject others, on eugenic grounds. This is truly the limit of unscientific absurdity. It had a pseudo-scientific warrant so long as we accepted the statistical ideas of human heredity, and thought that mankind could be generalised about, by the thousand, in that fashion. But in these days, when extensive pedigrees are being compiled, which show how brothers differ like black and white, just as Mendel's peas did, and for the same reason, it is too ludicrous that, when the necessity of these discriminations, even within a given stock or family, is apparent, we should be asked to swallow wholesale generalisations about such infinitely heterogeneous aggregates of individuals as social classes.

The False Start of Supposing there is a Biological Basis for Class Prejudice

Mr. and Mrs. W. C. D. Whetham did much service, some years ago, when they began to interest themselves in eugenics, by leaving biometry on one side, and making a fresh start with Mendelism; and it is so much the more disappointing and inexplicable that, with the pedigrees they have collected staring them in the face, they should find it possible to champion class against class, and to declare that there is a biological warrant for class-prejudice, as they have lately done. Nonsense is quite the politest word that can be applied to such assertions; and the bold political generalisations, usually taking the form of protests against social reform, which are based upon them may be valued accordingly.

Of course, we are only at the beginning of the new knowledge; and if genetics warrants as little definite action at the present time as is here asserted, every year makes a difference. The urgent need is for more knowledge, but it must be real knowledge, for we have had enough of the interminable calculations regarding what we now know to be mere nutritive fluctuations that are not inherited, and therefore have no bearing upon eugenics. Above all, we need rightly constructed pedigrees. Hitherto the genealogist has been concerned simply with family pride, not with the extension of natural knowledge; and "his mind has consequently been set on a demonstration rather of the origin and antiquity of his hero's qualities than of their distribution or absence among the collaterals."

The Need for Genealogical Tables Reading Downwards and Not Upwards

In a word, human pedigree-tables have been arranged to be read upwards instead of downwards. The table has been constructed like a fan, with its apex in the genealogist's hero, and its base widening, as far as possible, into his ancestry, the parental stock of each ancestor being represented by a pair. But to show how a character really descends we require the table constructed with its apex in one original individual who possessed the character, and from that apex to exhibit the distribution of that character among the diverging branches of his posterity. In other words, genealogists in the future must give us pedigree tables arranged to read downwards instead of upwards; and indeed our real knowledge of human heredity increases just in proportion to the number of such tables that we are gradually being provided with.

Our knowledge of heredity in man now requires only workers to collect the facts faithfully and patiently. How this can best be done the American school of eugenics have now begun to demonstrate with notable success; nothing resembling their work for quality and results has yet been attempted in this country. To that work our next chapter must be devoted, in the sure hope that, before long, similar inquiries will be set on foot here also. They do not require a rare order of intelligence, but only great faithfulness and patience. Anyone possessed of these qualities can increase the sum of knowledge.